THE PUZZLE OF SOCIAL ACTIVITY

THE SIGNIFICANCE OF TOOLS
IN COGNITION AND COOPERATION

by

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Linköping 2006
Abstract

This dissertation addresses the role of tools in social interactions, or more precisely the significance of tools in cognition and cooperation, from a situated cognition perspective. While mainstream cognitive science focuses on the internal symbolic representations and computational thought processes inside the heads of individuals, situated cognition approaches instead emphasise the central role of the interaction between agents and their material and social environment. This thesis presents a framework regarding tools and (some) of their roles in social interactions, drawing upon work in cognitive science, cultural-historical theories, animal tool use, and different perspectives on the subject-object relationship. The framework integrates interactions between agents and their environment, or agent-agent-object interaction, conceptualisations regarding the function of tools, and different ways in which agents adapt their environments to scaffold individual and social processes. It also invokes stigmergy (tool mediated indirect interactions) as a mechanism that relates individual actions and social activity. The framework is illustrated by two empirical studies that consider tool use from a social interaction perspective, carried out in settings where tools assume a central role in the ongoing collaborative work processes; a children’s admission unit in a hospital and the control room of a grain silo. The empirical studies illustrate theoretical issues discussed in the background chapters, but also reveal some unforeseen aspects of tool use. Lastly, the theoretical implications for the study of individual and social tool use in cognitive science are summarised and the practical relevance for applications human-computer interaction and artificial intelligence is outlined.
Acknowledgements

First of all, I wish to express my sincere thanks to Professor Tom Ziemke for being an excellent supervisor. I also wish to thank my friends and colleagues at University of Skövde, especially Jessica Lindblom, Jana Rambusch, and Henrik Svensson, for your support, encouragement, and all the discussions we have had. Special thanks also to Beatrice Alenljung, for being such a good teacher, mentor, and colleague throughout the years.

I also wish to thank my opponent Professor Mark Bickhard, and to express my gratitude to the examination committe: Professor Lars Niklasson, Professor Erik Hollnagel, and Associate Professor Henrik Artman.

A special thanks to Professor Hanna Risku for your encouragement and helpful discussions. Thanks also to Vera Lindros for reading and commenting on this thesis, and to Christine Olsson for designing the cover.

Thanks to all staff members at Kärnsjukhuset Skövde and Lantmännen Ek.för. for your participation in the empirical studies.

Last, but certainly not least, my deepest thanks to my family, for being there.
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Other conference and workshop papers


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Man is a tool-using animal…

– Benjamin Franklin

… without tools he is nothing – with them he is all

– Thomas Carlyle

We should resist neglecting or trivializing the commonplace. There are rewards for approaching nature with a naive curiosity and attempting to see the familiar in new ways.

– Provine, 1996
1. Introduction

This dissertation addresses the role of tools in social interactions from a situated cognition perspective. In contrast to mainstream cognitive science, situated cognition approaches acknowledge that cognition is not confined to "the inside" of the heads of individuals. Rather, external resources that include historical, social, and cultural (material and psychological) aspects need to be considered as well in order to fully understand cognition. However, despite the growing emphasis on including artefacts in the analysis of cognitive processes, the area still needs a more thorough understanding of just how and why artefacts play such an important role in cognition. Andy Clark, who is well-known for advocating the necessity of understanding the role of artefacts in human cognition, argues that

[...]the single most important task...is to better understand the range and variety of types of cognitive scaffolding, and the different ways in which non-biological scaffoldings can augment (or impair) performance on a task...The "Holy Grail" here is a taxonomy of different types of external prop, and a systematic understanding of how they help (or hinder) human performance. (2002, p. xx)

Mainstream cognitive science, which follows the dominant computer metaphor for the mind, has traditionally been based on a general consensus that cognition is best analysed and described in terms of internal, often symbolic, representations and the computational processes manipulating them (e.g., Pylyshyn, 1990). The main concern has been to analyse cognitive processes such as attention, perception, memory, categorisation, and problem-solving. These processes have generally been considered as operating independently of the environment, which has largely been reduced to inputs and outputs. Since the mid-1980s this view has been criticised from various directions for its overly narrow focus on the internal cognitive processes of individuals. With the realisation that people are strongly affected by, and possibly to some degree dependent on their environment, focus has since shifted to cognition as situated. In general terms, ‘situatedness’ means that cognition emerges from the close coupling between an agent and the environment; cognition that involves the mind, body, as well as the material, social, and cultural environment. With a shift of focus new interactive theories of cognition have emerged, such as situated cognition (Clancey, 1997; Clark, 1997) situated learning (Kirshner & Whitson, 1997; Lave, 1991; Lave & Wenger, 1991), situated action (Hendriks-Jansen, 1996; Suchman, 1987), situated translation (Risku, 2002), situated robotics/AI (Clancey, 1995b; 1997; Steels & Brooks, 1995; Ziemke, 2000), embodied cognition (Clark, 1997; Lindblom & Ziemke, in press; Svensson, Lindblom & Ziemke, in press; Varela, Thompson & Rosch, 1991), and last, but not least, distributed cognition (Hutchins, 1995a; Salomon, 1993). While such situated approaches have gained some insights into the issue of tools and interactions, situated cognition as such is still short of an understanding of the ways tools scaffold and affect people’s interactions. In other words, what is needed is a more thorough understanding of the role of tools in social interactions.
1.1 Guiding principles

As suggested by the title of this thesis, social activity and cognition can be viewed as a puzzle, where each piece is but one facet of the processes that take place between agents. While many pieces already fit nicely together, others are scattered and remain to be joined to them. The ‘pieces’ considered in this thesis are related to some or all of the following: interaction (between agents, and between agents and their environments), one or other kinds of objects (tools or artefacts), and cognition. The task I set out to accomplish here is to put some pieces together into new constellations as well as to add a few more pieces to the puzzle. The aim is not to provide a complete image of all the aspects of tool use in social activities and cognition. Instead my contribution to solving the puzzle is a framework that draws together individual and social activity, and the significance of tools in cognition and cooperation, that is, a step towards Clark’s “Holy Grail” (cf. above).

In this thesis it is assumed that cognition is not something that takes place solely on the ‘inside’, but instead involves external material resources as well as other agents (cf. Susi, Lindblom & Ziemke, 2003). Hence, this work falls within the area generally termed situated cognition. The term ‘situated’ has come to mean different things in different areas (cf., e.g., Ziemke, 2000). It has also been argued that the phrase ‘situated cognition’ itself is misleading since it implies that there is some kind of cognition that is not situated (Greeno & Moore, 1993), and in fact others argue that there is non-situated cognition (see, e.g., Wilson, 2002). However, exactly what ‘situated’ means (or does not mean), or how it should be defined is not the issue here. What is more important, generally speaking, is that situated cognition has provided an alternative approach to understanding and explaining cognition, one that has shifted focus from cognition as internal information processing to cognition as situated; agents, in this case people, are situated in a social, cultural, and historical environment, and cognition emerges from peoples’ interactions with that environment. This is what I refer to when I talk about cognition as ‘situated’.

As discussed in later sections, people are quite skilled in using environmental resources in ways that facilitate cognition, thus reducing cognitive effort. Furthermore, tool use affects an individual’s own cognition as well as people’s interactions, whether they are aware of it or not. Therefore tool use has been described as a way of controlling one’s own, as well as others’ behaviour (cf. Susi & Ziemke, 2001). Hence, the use of tools is one way of adapting the environment so as to facilitate and affect individual as well as social cognitive processes. Although the focus in this thesis is on tool use in social activity, it is not a matter of tool use and cognition in social processes as opposed to individual tool use and cognition. While much research has focused either on the individual’s (internal) cognition, or group level activities, the two are not separable, and there is no such thing as individual activity, since all activities are social (Leontiev, 1978); individual and social cognition are not easily (or even meaningfully) distinguished as two separate things since there is really no saying where one starts and the other ends. Therefore, if we are to gain a better understanding of tools and
cognition, we cannot focus on either individual or social activities. To paraphrase Rogoff (2003), a focus on either individual tool use or social activity is “as pointless as asking whether people rely more on their right leg or their left leg for walking” (p.65) (cf. Rambusch, Susi & Ziemke, 2004; Susi, 2005). Instead individual and socially distributed cognition needs to be considered in interaction (cf. Salomon, 1993). The point is that while the focus in this thesis is on the role of tools in social interactions, individual tool use cannot be disregarded as, in fact, social interaction sometimes takes the form of individual tool related actions, which is discussed in later chapters.

The term ‘social interaction’ will also not be further defined here. Instead, when discussing social interaction, I mean, in a general sense, the dynamic process that takes place as agents do something together. In addition, many of the interactive processes discussed in this thesis concern direct or indirect cooperation and coordination of activities. The terms artefact, tool, and tool use, on the other hand, are described in more detail. As seen in later sections, these terms have proven difficult to define, and in fact, there are no generally accepted and coherent definitions. The terms artefact and tool are also used interchangeably in much of the literature, even though one or the other is usually preferred depending on the issue under discussion. In the background chapters of this thesis these terms are used in much the same manner as in the literature, referring to external material objects unless noted otherwise. My view on artefacts, tools, and tool use is discussed in more detail in Section 2.6, which provides an initial description of tools and tool use. In Section 6.1 that description is revisited and elaborated on. However, let us already at this point take a look at part of the final description arrived at in Section 6.1, so the reader will know how I consider these terms. It reads:

Artefacts belong to a general, wide category that includes manufactured (modified, etc.) objects in our surroundings. These are the things that are ‘there’, but are not necessarily used in order to achieve something.

A tool, on the other hand, is any object perceived by an agent (or agents) as a tool within an unfolding situation, and used as a mediator between him/herself and the environment. More specifically, a tool is an object ascribed with a meaning of usefulness, in the sense that it can be used to achieve some purpose (whether the agent is aware of it or not).

Through the use of tools cognition is mediated and distributed between individuals and their material and social environments. As such, tools scaffold and mediate individual as well as inter-individual processes, and they extend the bodily and/or cognitive capacities of agents to operate within a given situation.

Tool use also provides a means of coordinating social processes, which relates the individual and social level of activity. The achievement of coordinated social behaviour can be explained through the principle of stigmergy, that is, indirect interaction through the use of tools.
At this point we will leave the description of tools and tool use adopted in this thesis, and allow the underlying details to become clear in later sections. Before proceeding with the details of how to accomplish the task of describing the significance of tools in social activities and cognition, the formulation of a framework, and the benefits thereof, I will further explain the motivations for addressing this issue in the first place.

1.1.1 The significance of tools and artefacts

In the era of the prevailing computer metaphor for the mind, the role of artefacts and tools, especially in social interaction, has mainly been left unattended, while social processes and language, for instance, have received much attention. Research in the area of social cognition has resulted in a wealth of theoretical constructs on behaviour (see, e.g., Augoustinos & Walker, 1995; Fiske, 1992; Levine et al., 1993; Thompson & Fine, 1999; Semin & Smith, 2002). However, social cognition theories have generally taken a computational approach and considered social processes in terms of the individual’s internal representations of social aspects, while the role of external material resources in such processes has been disregarded. Likewise, linguistic research has resulted in a number of theories on language development and construction, but there is nothing comparable for tool behaviour, which is largely an overlooked issue (Gauvain, 2001; Smitsman, 1997; Want & Harris, 2001; Wynn, 1993). As pointed out by Wynn (1993, p. 392), “[t]here is almost no concern with how tools are made and used and there are no well-developed theories of how sequences of tool-use are constructed” (see also Preston, 1998; Wynn, 1991)\(^1\). It is strange that the use of artefacts and tools has been neglected to such an extent, since, as argued by Woods (1998), one of the fundamental findings of cognitive science is that “artefacts shape cognition and collaboration” (p. 168). Similarly, according to Streeck (1996, p. 366), “[o]ur image of human competence would…remain partial and distorted unless we understand that it is both internal and external, and that the ‘internal mind’ could not function at all if it were not surrounded by mindful things that have evolved along with it”. Furthermore, it has been argued that material artefacts and tools have a similar role in cognitive processes as that of language, “in particular they constitute the other major form of cognitive mediation between individual and world” (Preston, 1998, p. 514, emphasis added). Of course, language is also sometimes considered a tool, or even ‘the ultimate artefact’ (cf. Clark, 1997; Gauker, 1990). In this thesis, however, as already mentioned, the focus is on material tools and language is therefore considered a tool among other tools.

Another issue, closely related to artefacts and tools, is technology\(^2\), which is often generally considered “a defining feature of human culture” (Lockman, 1994).

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1 An exception is Baber’s (2003) more recent tool use theory, which considers some aspects of tool use, further discussed in Section 2.4.3.

2 Here I am referring to technology as objects (the artefacts, or products, of technology). For further distinctions and definitions on technology, see, e.g., Ingold (2000) and Mitcham (1994).
Technology has been considered as the key to the advancement of modern civilisation, and "[f]or many centuries, Western\textsuperscript{3} thought has been dominated by the idea that the mission of mankind is to achieve mastery over nature" (Ingold, 2000, p. 312). The means for achieving such mastery would be technology. However, the use of tools and technology is not only a means for ‘achieving mastery’, but also something that affect people’s cognitions. Technology used to be a central concern of Western anthropology, but along with the cognitive revolution of the 1950s and 1960s, which placed culture inside the head of the individual, material culture was largely disregarded, and has been ever since (Arievitch, 2003). With the development of technology, material things in all kinds of forms have become ubiquitous to the extent that they tend to be invisible, or go by unnoticed. As Gauvain (2001) points out, one of the difficulties in understanding these things, or ‘cultural tools’ as she terms them, lies in the fact that they are often such an integrated part of what we do that their contribution to our activities is easily overlooked; they “often have a seamless, invisible quality, temporarily organizing the flow of action, and when the action is completed the tools simply ‘vanish into it’” (p. 141). Perhaps it is this quality of ‘invisibleness’ that leads us to think we are smart on our own, when in fact in many cases it is the use of artefacts that makes us smart (Clark, 1997; Norman, 1993), and even provides us with ‘artefactual intelligence’ (de León, 2003). Schiffer (1999), an anthropological theorist, is straightforward in his critique of scientists’ blindness for artefacts:

Might [we] not wonder how social scientists, who like all other people spend the entirety of their time engaged with artifacts (especially books and chairs and computers), could be so oblivious to the medium that envelops them? People’s lives are spent shaping and responding to this material medium, yet social scientists cannot see it for what it is, much less understand its pervasive influence. Instead, human investigators lavish attention on the sounds that people produce, on the specialized artifacts that encode or record the sound, and on the social, cultural, and biological bases of sound production, reception, and interpretation. Preoccupation with these phenomena...has seriously skewed the study of human behavior. Apparently, total immersion in the material medium has blinded social scientists to the distinguishing characteristic of their species – of their lives. (Schiffer, 1999, p. 4)

Although Schiffer’s critique concerns the social sciences, the same point certainly also applies to cognitive science. Schiffer further argues that “[p]revious investigators have ignored what might be most distinctive and significant about our species: human life consists of ceaseless and varied interactions among people and myriad kinds of things. These things are called ‘material culture’ or, better, artifacts” (p.xx). Furthermore, with regard to social interactions – another ‘significant aspect of our species’ – Schiffer even goes as far as to claim that “[i]t is a mistake of cosmic proportions to arbitrarily abstract ‘interpersonal’ and ‘social’ interactions from human life and study them apart from the artefacts in which they are embedded” (Schiffer, 1999). Moreover, considering the ubiquity of interactions between

\textsuperscript{3} The term ‘Western’ refers to what might be called the Anglo-American research tradition (Ingold, 2000).
people and artefacts, also the idea of an independent individual cogniser, or 'solo intelligence' is, as Pea (1993) puts it, nothing but a theoretician's fantasy.

Even though Schiffer’s argument applies to much research it would be presumptuous to claim that artefacts have been neglected altogether, and indeed that is not the case. On the contrary, there are several well-known descriptions and perspectives on different kinds of tool use, such as distributed cognition (Hutchins, 1995a), cognition and tool use (Baber, 2003; Keller & Keller, 1996), and various workplace studies (see, e.g., Goodwin & Goodwin, 1996; Heath et al., 2000). Furthermore, the record of human tool use dates back some 2.5 million years (Gibson & Ingold, 1993; Odell, 2000; Wynn, 1991; 2002), when the oldest known tools, the so called ‘Oldowan’ stone tools (found at Olduvai Gorge in Tanzania) were made by early hominids. For a long time, it was believed that tool use was a uniquely human characteristic, which led to Benjamin Franklin’s well-known characterisation of man as a tool-using animal (Hewes, 1993). Indeed, humans are ‘tool-using animals’, and today tools are ubiquitous.

Although tools, or more commonly artefacts, and the way they figure in social contexts, have attracted some attention in recent years, there is no coherent view on how people employ artefacts to facilitate social cognitive processes, and there are few theories concerned with tool use and cognition. Research on tool use has to a large degree focused on the individuals’ tool use (like the external cognition view of, e.g., Scaife & Rogers, 1996; Zhang & Norman, 1994). Furthermore, most tool related concepts available in the literature have also been developed in the context of individual tool use. With the rise of situated cognition perspectives, emphasis has been placed on the interaction between agents and environments, but the role of tools (or artefacts) in cognition has still, to a large extent, remained a neglected issue. A notable exception is the distributed cognition approach, which focuses on the organisation of socio-technical systems and the way information (representations) are transformed and propagated in the very system of people and artefacts during the performance of a task (Hutchins, 1995a). Research in situated/distributed cognition approaches has shown that external tools play an important part in individual as well as inter-individual cognition. Tools mediate and scaffold peoples’ cognitions, thus allowing them to extend their cognition into the external world. Yet, there is no thorough understanding of tool use in social interactions. Hence, the situated cognition approach is in need of a more thorough theoretical understanding and explanation of agent-environment interactions, as well as the cognitions involved. The need for more research on this issue has been articulated within several research areas, among them (more recent approaches to) cognitive science (Clark, 2002; Kirsh, 1996), distributed intelligence/cognition (Pea, 1993; Perkins, 1993), developmental and cultural psychology (Gauvain, 2001; Lockman, 2000; Preston, 1998), anthropology (Schiffer, 1999; Wynn, 1993), ethnographical and other workplace studies (Heath et al., 2000; Heath & Luff, 1996), situated robotics (e.g., Ziemke et al., 2004), and human-computer interaction and computer-supported cooperative work.
(Ackerman, 2002; Dix et al., 2004; Dourish, 2001; Perry, 2003; Robertson, 2000). In sum, what all these sources point out is the need for further research on, and a more thorough understanding of, the ways in which artefacts affect human behaviour, how they influence people’s interactions, and how people adapt and employ artefacts to facilitate their cognitions.

1.1.2 Perspectives and contributions
The work described in this thesis is undertaken from a situated cognition perspective. The idea of examining tool use more closely is, of course, not a novel one. However, this work is unique in that it combines theoretical ideas and perspectives from many different areas. These include cognitive science, historical perspectives of cultural-historical psychology and different views on the relationship between agent and environment, as well as animal tool use. Furthermore, this work focuses on social interactions, in contrast to individual tool use.

Based on the literature surveyed in this thesis, some theoretical ideas and perspectives from different fields have been integrated into a conceptual framework for understanding tool use in social interactions. The framework includes the general model of human activity found in cultural-historical activity theory, tool/artefact related concepts, and a principle for explaining the relation between individual and collective activities. Hence, the framework integrates conceptualisations of the different functions of tools, individuals, social activities, and their interrelations. The theoretical background and the ensuing framework constitute one major part and contribution of the present work.

Another contribution of this thesis comprises the two empirical studies concerning tool use and interactions. The studies illustrate some of the theoretical issues discussed in the background chapters. However, as described in later sections, the empirical part of this work not only illustrates some proposed ideas, but also reveals some unforeseen aspects of tool use. Thus, some knowledge gained from the empirical studies has also been included in the framework.

A third contribution consists of what the present work contributes to different areas of research. Firstly, this thesis presents a situated cognition perspective, with the aim of contributing some further knowledge to a situated view on human activities. While situated cognition has diverged onto a new track, much focus has been placed on the social aspects of situatedness, and it is my purpose to draw attention to the significance of tools in social activities. Insights into the matter of tool use can thus provide us with further understanding of the situated nature of human activities. Furthermore, considering the influence of situated approaches in other areas concerned with interactions and the use of tools, this thesis can potentially contribute to research in such disciplines.

Two areas concerned with people’s interactions with tools and technology are, of course, human-computer interaction (HCI) and computer-supported
cooperative work (CSCW). In these domains, technical aspects used to be considered a primary issue, and users were of secondary importance, but focus has now shifted to a consideration of agents and context to a larger extent. Nevertheless, there is still relatively little understanding of the ways in which technologies influence interactions between people and the way people actually make use of artefacts (Ackerman, 2002; Perry, 2003). In CSCW a number of problems have been identified, among them the so called “socio-technical gap”, which refers to a gap between what is socially desirable and that which is technically feasible (Ackerman, 2002; Erickson & Kellogg, 2002). Technological innovations have not proven successful, and one of the challenges is to understand the ways in which technologies affect people’s interactions (Eckert & Boujut, 2003; Heath et al., 2000). Considering the influence of situated approaches on current HCI/CSCW research, a better understanding of situated cognition can also prove beneficial for research in these disciplines.

AI research is faced with a similar situation, that is, limited understanding of the role of the environment. Further knowledge on tool use and environment interactions in cognitive science can thus also contribute to artificial and robotics research. AI is, practically by definition, concerned with intelligent artefacts of one type or another (computers, robots, etc.). Somewhat ironically, however, work in AI, artificial life, robotics, etc., has so far paid very little attention to how such systems themselves could make use of (other) artefacts (Ziemke et al., 2004), possibly due to a poor understanding of the issue in the first place. Work on this subject in artificial life research is very limited. Studies are typically restricted to simplified scenarios and simulations at a very abstract level, for example disregarding actual sensorimotor interaction between agent and environment/artefact, such as Ugolini and Parisi’s (1999) simulations of cultural and technological evolution. Alternatively, they are limited to artefacts and social interactions of very limited complexity, such as robotic models inspired by stigmergic collaboration between social insects (e.g., Beckers et al., 1994; Holland & Melhuish, 1999) (cf. Agre, 1995). Given that (material) artefacts and language constitute the two main mediators between the individual and the world, and considering that language has been studied in thousands of AI models and research papers for at least five decades, it seems obvious that AI has some catching up to do with regard to modelling the role of tools/artefacts in (social) cognitive processes. Thus, further knowledge on tool use and environment interactions can also contribute to AI and robotics research.

1.1.3 About this thesis
Thus far, I have described what this thesis is about, but perhaps I should also say a few words on what it is not about. There are, of course, several areas related to interactions and the use of tools that can contribute to a deeper understanding of this issue. Such areas include, e.g., developmental psychology (development of tool using skills) (e.g., Dent-Read & Zukow-Goldring, 1997; Lockman, 2000, 2001; Smitsman & Bongers, 2003; Thelen et al., 2001), neuroscience (which is currently advancing in knowledge on
tool use; e.g., Berti & Frassinetti, 2000; Johnson-Frey, 2004; Maravita & Iriki, 2004), and embodied cognition (the role of embodiment in tool use and interactions) (e.g., Enfield, 2005; Goodwin, 2000; Streeck, 1996). Even though these areas are important for a deeper understanding of human tool use, they are not included in this thesis. Another issue not included is linguistic research (semantics, etc.). Instead, language is considered a tool among other tools. Obviously, not everything can be included in one thesis, and therefore these different areas are only briefly mentioned.

As previously mentioned, the current work may have implications for HCI, CSCW, and situated robotics/AI. This work is not, however, concerned with developing some method for workplace analysis or how to improve interactions with tools or technology, nor is it concerned with how to develop more advanced AI models. Rather, in these areas, along with situated cognition, it has been realised that we have limited understanding of the role of artefacts in human activities, and the present work aims at providing further insight into this matter, which in turn may be used for further work in the above areas.

It should be noted that in the following chapters, the use of quotes are rendered in their original form (with or without italics, and some in U.S. English) unless indicated otherwise.

### 1.2 Overview

Chapter 2 begins with a survey of current situated cognition research. More specifically, this chapter includes a discussion of situated action (Suchman, 1987), which can be seen as the starting point for an alternative to mainstream cognitive science. In contrast to the prevalent view on cognition as information processing and plan-based behaviour, the situated approach emphasises the mutual construction of meaning in unfolding situations, and, hence, the interaction between individuals and their environments. This chapter also discusses distributed approaches to cognition, which have clearly taken a step away from the traditional information processing view of cognition, and instead emphasise that cognition is distributed between people and the artefacts they use (Hutchins, 1995a; Salomon, 1993). Furthermore, with regard to the notion of cognition as distributed between agent and environment, this chapter also includes a discussion regarding the bounds of cognition. The discussion is subsequently narrowed down to artefacts, tools, and their use, with focus on different views regarding definitions and categorisations. A recent theory specifically concerned with tools and cognition (Baber, 2003) is also discussed in more detail.

Furthermore, I will more closely examine cognitive artefacts, and some specifically artefact related concepts. This chapter also provides an initial description on how tools and tool use are considered in the present work (the issue is revisited in Chapter 6).

Chapter 3 explores some historical perspectives related to tools and interactions. The first part discusses three theoretical works on the relation between agents and their environments, or subject and object. The theories
are those of von Uexküll (1982; 1992), Heidegger (1927/1962), and Gibson (1986), and specifically the concepts of functional tone, equipment, and affordance. The way the subject-object relationship is regarded is relevant to current views on agent-environment interactions, as discussed in later chapters. The remainder of Chapter 3 describes Russian cultural-historical research. More specifically, the focus is on Vygotsky’s (1978) cultural-historical theory of development, Leontiev’s (1978) cultural-historical activity theory, and Gal’perin’s (1978/1992) systematic formation of mental actions and concepts. Common to these lines of work is the notion of mediation, and an emphasis on the material and social nature of human activities. Even though cultural-historical research dates back to the early 1900s, it is remarkably up-to-date and today we see a renewed interest in cultural-historical research that influences much situated cognition research (e.g., Clancey, 2002; Hutchins, 1995; Kirshner & Whitson, 1997). There is nevertheless one important difference; while Russian research has focused on individuals, mediation, and internalisation (the individual’s development), situated cognition research in the West has come to focus much more on social processes and cultural aspects, and has paid much less attention to matters of tool mediation and the individuals themselves. Similar to earlier work on the subject-object relationship, cultural-historical approaches are also relevant for current situated research.

In Chapter 4 the subject of interest in this thesis, i.e., humans and their use of tools, is considered in relation to tool use and the adaptation of the physical environment (for collaborative purposes) in other species. Firstly, this chapter considers primatology, and more specifically, to tool use in great apes. Primatology research has provided knowledge, not only of non-human primate tool use, but also advanced our understanding of human tool behaviour. This chapter also takes a closer look at tool related behaviour in social insects. Social insect behaviour exhibits a coordination paradox in that each individual seems to act on its own, while, at the same time, there is coordinated behaviour at the social level. This coordination paradox has been explained through the principle of stigmergy, i.e., a mechanism that explains the relation between individual and social levels of behaviour (Theraulaz & Bonabeau, 1999). Subsequently, some generalisations of human and non-human tool behaviour, based on Chapters 2-4, are abstracted. The generalisations are repeated in Chapter 5 (Section 5.3.3), in the discussion of the empirical studies in relation to the theoretical.

Chapter 5 is concerned with the empirical part of this thesis. The first section discusses methodological issues and the approach chosen for the empirical studies. The following sections describe two case studies in settings where artefacts assume a central role in the ongoing work processes. The first study was conducted at the children’s admission unit in a hospital, and focuses on individual tool use within a social context. The second study was conducted in the control room of a grain silo, and focuses

4 In this thesis the term ‘Western’ refers in a general sense to what might be called the Anglo-American research tradition, in contrast to the research tradition in Soviet psychology.
on tool use in social interactions. The studies serve to illustrate some of the theoretical aspects discussed in the background chapters, but they also reveal some additional unforeseen issues.

In the first part of Chapter 6, the initial description of tools and tool use (discussed in Chapter 2) is elaborated, and my view of these terms is presented. This is followed by a discussion concerning the framework concept, and its use in this thesis. The following section draws together theoretical aspects from different fields and some of the findings from the empirical studies, into a framework for understanding tool use in social interactions.

Chapter 7 provides a summary of the contributions of this thesis, and discusses some implications for the situated cognition view, and a few other related areas. This is followed by some reflections regarding the present thesis, and the final section identifies some issues for future research.
2. Situated cognition and tool use

This chapter discusses the current advancements in research on tools and cognition. Section 2.1 describes the situated nature of activity, while Section 2.2 describes contemporary approaches specifically concerned with cognition as distributed among people and artefacts. Section 2.3 subsequently discusses where the bounds of cognition should be drawn. In Section 2.4 the discussion is narrowed down to artefacts, tools, categorisations, and a recent theory on tool use. Section 2.5 focuses on artefacts/tools in relation to cognition, and some specifically artefact related concepts. The (initial) view on tools and tool use adopted in this thesis is described in Section 2.6.

2.1 The situated nature of activity

The importance of considering the role of the environment in order to understand human behaviour has been emphasised under various labels, at least since the early 1900s. However, cognition as a situated phenomenon, with an emphasis on the interaction between agents and their environments, did not emerge as a paradigm until the 1980s with the rise of situated action\(^5\) or activity (Lave, 1988; Suchman, 1987). Situated approaches, broadly considered, seek to overcome the Cartesian dualism of mind and body, and instead emphasise the interaction between mind, body, and world, maintaining that cognition emerges from the interactions between individuals and their material and social environment.

An emphasis on interaction between individuals and their environments, and external resources being an important part of human activities can be found, for instance, in the work of educational theorist Dewey, which was developed during the first decades of the 1900s. Dewey promoted progressive education, as opposed to traditional education, and in *Experience and Education* (1938/1998), he emphasised that experience does not occur in a vacuum, that is, within the individual's mind and body. Instead it is external material and social sources that give rise to experience. In his view, an “experience is always what it is because of a transaction taking place between an individual and what, at the time, constitutes his environment” (ibid., p. 41). The environment here “is whatever conditions interact with personal needs, desires, purposes, and capacities to create the experience which is had” (p. 42). The conditions, or ‘objective conditions’ (those that are external to the individual), in a situation include other people, what they say and do, the material objects with which the individual interacts, and the total social set-up of the situation. The enduring value of experience (its ‘usefulness’ so to speak, in situations other than the one in which it was gained) depends on the quality of the experience itself. What a person gains in knowledge and skill in one situation affects his understanding of, and how he deals with, following situations. Dewey argued that the objective conditions of a situation, to some extent can be regulated. Thus, the educator can directly influence the experience of others, and it is the

\(^5\) The term ‘situated action’ had been discussed earlier though, e.g., in Wright Mills (1940).
educator’s duty to arrange these conditions in a way that “promote having desirable future experiences”. Dewey’s emphasis on the role of external resources for experience and the idea of regulating the external conditions in order to achieve desirable experiences was, as seen in Section 3.4, echoed in Gal’perin’s (1978/1992) specific interest in the way external material objects provide a means for forming mental actions with desired properties.

The situated action paradigm, although perhaps not directly based on Dewey’s theories, reflects the basic concept of considering the relation between an individual and the environment. More specifically, as formulated in the 1980s, this paradigm sought to “explicate the relationship between structures of action and the resources and constraints afforded by physical and social circumstances” (Suchman, 1987, p. 179). This ‘new’ paradigm emerged as a reaction to, in Suchman’s terms, machine intelligence, which, at the time, was based on the prevalent view of symbolic information processing in cognitive science, and the notion of plan-based human behaviour. Suchman’s (2003) main point was that plans should be viewed as resources produced and used in actions, i.e., they are descriptions that represent our actions, rather than control structures that determine the course of actions (cf. Clancey, 1995a; Mead, 1934). From a plan-based behaviour perspective, as described by Suchman (1987), plans are action sequences performed in order to reach some pre-specified goal, and the plans are pre-requisite to and prescribe actions. From a situated view, however, actions are not based on pre-specified plans, but instead are taken in the context of particular, concrete circumstances. The difference is highlighted in the example of a European and a Trukese navigator, where the former exemplifies the traditional cognitive science model of purposeful action, and the latter a situated view on purposeful action. While the European starts off with a plan guiding his action, the Trukese instead begins with an objective and relies on unique circumstances that cannot be anticipated in advance. Another well-known example is a canoeist running a series of rapids. Before descending, the canoeist stops for a while to plan how to descend the rapids, but once he/she begins the plan is abandoned, and he/she falls back on “whatever embodied skills are available” to him or her (ibid., p. 52). The purpose of the plan, then, is to orient him to obtain the best possible position from which to use the embodied skills on which the success depends. The point being made is that all activity is fundamentally concrete and embodied, and however planned purposeful actions are, they are inevitably situated actions. Hence, plans are resources for situated action, but they do not, in any strong sense, determine the course of the actions; plans are simply not executed in the action. Viewing actions as mere executions of plans would be, as Ingold (1993b) maintains, to attribute intelligence to the operation of a cognitive device, “which is somehow inside man and which, from this privileged site, processes the data of perception and pulls the strings of action” (p. 431). In Suchman’s view we all have to act like the Trukese as we can never fully anticipate the circumstances of our actions, circumstances that are continuously changing. The consequence is that our actions are never planned in the strong sense that [traditional] cognitive science would have it. Rather, plans are best viewed as a weak resource for what is primarily ad
hoc activity. It is only when we are pressed to account for the rationality of our actions, given the biases of European culture, that we invoke the guidance of a plan. Stated in advance, plans are necessarily vague, insofar as they must accommodate the unforeseeable contingencies of particular situations. Reconstructed in retrospect, plans systematically filter out precisely the particularity of detail that characterizes situated actions, in favor of those aspects of the actions that can be seen to accord with the plan. (1987, p.ix)

Similarly, Ingold (1993b) points out that we do construct plans and representations but that they are brought forth through the intelligent activity of ‘thinking’. Plans are the product of action and even when plans precede actions they serve as guidelines “rather than as programmes that ‘call up’ the action as an automatic behavioural output. For the action issues from the agent, not from the plan…and the quality of intelligence is not contributed by the plan but is rather immanent in the action itself” (p. 431). The situated action view on the use of plans has caused considerable debate (see, e.g., Greeno & Moore, 1993; Schwartz & Martin; 2003; Suchman, 2003; Vera, 2003; Vera & Simon, 1993), and a common (mis)reading is that there is no use of plans or that they are irrelevant once a situation is unfolding (Suchman, 2003). However, as Suchman points out, plans are projections of future actions, and those projections are relied on during the course of action, but moment-to-moment interactions between an individual and the environment are not pre-specified and determined by a plan. The emphasis on the role of external conditions has also caused criticism that situated action is behaviouristic (e.g., Nardi, 1996). But, according to Suchman, behaviour is not reactive and contingent on the external world and actions are not behaviouristic ‘in any narrow sense of that term’. There is no assumption that the significance of action can be reduced to uninterpreted bodily movements, rather behaviour is “reflexively constitutive of its significance which, in turn, gives behavior its sense” (Suchman, 1987; 2003, p. 304).

Another problem with machine intelligence, besides its basis on ‘human behaviour according to plan’, was the notion of human-machine interaction, which implies that computational artefacts are interactive, that there is a mutual intelligibility, or shared understanding, as in human-human interaction (Suchman, 1987). Suchman further describes computers as being given a character of purposefulness since the reactions of computers are not random, but designed. The reactivity of computers leads to an association with social objects. In addition, the behaviour of computers, and one’s control of them have a linguistic component, which adds to the tendency of employing terms like dialogue and conversation, terms borrowed from human interaction, to describe what happens between people and machines. While this description applied to the situation at the time, Suchman (2000) notes that current machine intelligence, based on

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6 Suchman describes a project of designing an “intelligent, interactive” computer based interface, attached to a complex photocopier, which was meant to serve as an expert advisor. The design was based on the planning model of human action and communication, then prevalent in artificial intelligence. The question was not whether artificial intelligence is possible, rather, Suchman addressed the issue of ‘interaction’.
technologies like neural networks, situated robotics, genetic algorithms and the like, still carries the same interaction metaphor; personified computational artefacts are attributed with a capacity for intelligent, interactive behaviour.

In the context of human-machine interactions, Suchman makes a point on the *ocurrentness of representations*. She argues that as long as an action proceeds smoothly it is transparent, and representations occur only when an action becomes problematic. Likewise, in actions including objects, the objects tend to be ‘transparent’, or ‘disappear’, as long as their use proceeds well. According to Suchman, breakdowns occur, for instance, when some equipment is unfamiliar. Rules and procedures needed in the handling of the unfamiliar equipment are not self-contained or foundational. Instead they depend on, and are derived from the situated action that they represent. Consequently, situated actions are not made explicit by rules and procedures, rather, when the situated action becomes problematic “rules and procedures are explicated for purposes of deliberation and the action, which is otherwise neither rule-based nor procedural, is then made accountable to them” (1987, p. 54).

While the situated action view most specifically points to some problematic issues in traditional cognitive science, it is, as Engeström (1999) points out, limited in that it does not account for socially distributed or collective aspects. Neither does it account for artefact-mediated or cultural aspects of purposeful human behaviour (artefacts as mediators are further discussed in Chapter 3). While there is a point in that, Suchman’s situated action perspective was more a starting point for a situated view on cognition, rather than a fully formed theory. However, distributed and collective aspects are considered within Anglo-American socio-cultural research, which, similar to the situated action perspective, emphasises the interactions between individuals and their environments. Socio-cultural research has developed from and is influenced by Russian cultural-historical research (Strum et al., 1997), with an important difference though. Cultural-historical research has focused much more on mediation, cultural artefacts, and the way external material processes become internalised, than on social aspects (cf. Chapter 3). Furthermore, even though social aspects are emphasised they are usually not included in analyses (Arievitch, 2003). Socio-cultural research, on the other hand, largely discards issues concerning material objects and internalisation, and instead focuses on social scaffolding, apprenticeship and learning as a social process (Arievitch, 2003; Chaiklin & Lave, 1993; Pea, 1993; Resnick et al., 1991).

The emphasis on social aspects is obvious, for instance, in the concept of *socially situated practice*, or *situated learning*, which emphasises the relational interdependency of agent and world, activity, meaning, cognition, learning, and knowing (Kirschnr & Whitson, 1997; Lave, 1991; Resnick et al., 1991: Rogoff, 2003; Rogoff & Lave, 1984). In general terms, learning is considered to be situated in *social* practices in the lived-in world, and learning has been conceptualised as *guided participation* (Rogoff, 1990),
cognitive apprenticeship (Brown et al., 1991; Keller & Keller, 1996), and legitimate peripheral participation (Lave & Wenger, 1991). The situated learning approach differs notably from traditional education and learning theories in their view on the nature of human knowledge. Generally, cognitive science equates knowledge with descriptions of knowledge, that is, representations. Knowledge is considered a set of ‘objective facts’ stored in the form of representations, and thereby learning becomes a matter of ‘transmitting’ knowledge from teacher to learner (Clancey, 1995a). From a situated learning perspective knowledge is not a set of facts or descriptions. Rather, as described by Clancey (ibid.), knowledge is an analytic abstraction and knowledge representations such as textbooks are descriptions, not knowledge itself. Therefore, learning is not a matter of transmitting or transferring facts from one individual to another, instead “learning is a process of conceiving an activity” (Clancey, 1995a). Subsequently, learning comprises more than what is taking place within the individual mind; it is affected, for instance, by social norms, the individual’s interpretation of a situation and conceptualisation of his/her role. Generally, learners are regarded as participants, and it is argued that learning is improvised in practice. Thus, “[n]ewcomers become oldtimers through a social process of increasingly centripetal participation, which depends on legitimate access to ongoing community practice” (Lave, 1991, p. 68). Thereby learning leads to becoming a member or participant of a sustained community of practice. Subsequently, if we are to understand what is learned we need to understand how it is learned, and to understand both the formal and informal institutional structures in which the learning takes place. However, as mentioned before, situated learning approaches (and situated action in general) strongly emphasise the social side of interaction and tend to disregard or only implicitly consider the role of material resources in learning. The question of understanding ‘how something is learned’ is the basic issue also in Gal’perin’s cultural-historical research, which is discussed in Section 3.4, except that he focused on the material side of learning (and paid relatively little attention to social aspects) (see e.g., Arievitch, 2003; Rambusch, in press, regarding the different foci in situated learning and cultural-historical research, and the way they complement each other).

Thus far only some of the basic concepts of situated action or activity have been discussed, and this approach has developed in different directions and there are various perspectives and viewpoints, each emphasising different aspects of situatedness (e.g., Clancey, 1997, Clark, 1997; Goodwin, 1995, 2000; Keller & Keller, 1996; Kirshner & Whitson, 1997; Lave & Wenger, 1991; Resnick et al., 1991; Rogoff, 2003). Empirical studies, in which the situated action approach has been used as a theoretical grounding include e.g., airport operation centres (Goodwin & Goodwin, 1996; Suchman, 1997), underground transportation systems (Heath & Luff, 1996), and design (Lueg & Müller, 1996).

To summarise, situated action emphasises the relation between actions and the environment, that is, the material and social circumstances. It resists
the idea that human behaviour is based on prespecified plans. Instead, plans are identified as resources for action, but they do not predetermine and specify the course of actions in an unfolding situation. Situated learning approaches, which place even more emphasis on the ‘social circumstances’ of activities, take learning to be ‘improvised in practice’ and as a socially situated activity. As participants or apprentices, learners become members or participants of a sustained community of practice. In general, situated action/activity approaches little consider the role of artefacts. The next section considers an approach that addresses artefacts and social processes in greater detail.

2.2 The distributed nature of cognition

It has been said that the mainstream “definition of cognition has been unhooked from interaction with the world” (Hutchins, 1995a p. 367), but as seen in the following, interaction with the world is at the centre of distributed cognition approaches, which clearly have taken a step to hooking cognition to interaction with the world again. Cognition as a distributed phenomenon is one of the more recent developments that offer an alternative to cognition as individual internal processing. The notion itself, however, that cognition involves more than the individual mind can be found in much earlier work, e.g., by Dewey, as discussed in the previous section. The same basic idea has also been traced back to Münsterberg (Cole and Engeström, 1993). Münsterberg, who adopted the ideas of Wilhelm Wundt, wrote:

A letter, a newspaper, a book, exists outside of the individuals themselves, and yet it intermediates between two or between millions of persons in the social group...The book remembers for the social group, and the experiences of the group, objectively recorded in it, shape the social action and the social thought. The letter can connect any distant social neurons; the paper may distribute the excitement from one point of a social group to millions of others. Every objectified expression becomes a social short cut. (Münsterberg, 1914; in Cole & Engeström, 1993)

This early description of the role of external resources is very much to the point of current theories of distributed cognition, though the term ‘distributed cognition’ itself assumes a somewhat different meaning in different lines of work. According to some opinions, cognition in general is principally distributed, even though individual cognition should not be dismissed; others distinguish individual and distributed cognition, and see them in an interdependent dynamic interaction (Salomon, 1993). Another view is that of joint cognitive systems (JCS; Hollnagel & Woods, 2005, see also Hollnagel & Woods, 1999), with a focus on how complex systems maintain control of a situation. This approach shifts focus from cognition to performance, and takes the performance characteristics of a JCS as its unit of analysis. Probably, the most well-known approach to distributed cognition is Hutchins (1995a) Distributed Cognition (DC), which focuses on understanding the organisation of complex cognitive systems. This

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7 Although Wundt is mostly known as the founding father of experimental psychology, half of his work was devoted to a cultural, descriptive approach to knowledge (Cole and Engeström, 1993).
framework takes a distributed, socio-technical system as its primary unit of analysis, and it is explicitly cognitive in that it is concerned with how information is represented, and how representations are transformed and propagated in the performance of tasks (Hollan et al., 2000; Hutchins, 1995a). DC uses a classical cognitive approach, slightly modified in order to be applicable to a unit of analysis that is larger than a person. According to Hutchins (1995b), thinking about organisations as cognitive systems is not new. What is new is

the examination of the role of the material media in which representations are embodied, and in the physical processes that propagate representations across media. Applying the cognitive science approach to a larger unit of analysis requires attention to the details of these processes as they are enacted in the activities of real persons interacting with real material media. (p. 266)

Taking a socio-technical system as the unit of analysis makes it possible to directly observe the many representations that are in the system, yet outside the individual’s head. This provides a way of perceiving the cognitive properties of a system, without having to infer anything about the processes that operate inside the individual’s head. A system has observable properties and representations, while individuals do not. This approach is based on three principles, namely that cognition is **socially distributed**, it is **embodied**, and it is **inseparable from the study of culture** since agents live in complex cultural environments. **Socially distributed** cognition includes both phenomena that emerge in social interactions as well as interactions between people and structures in the environment. The concept of cognition as **embodied** gives the human body and the material world a central role, while the organisation of mind is regarded as an emergent property of interactions among internal and external resources. Cognition is also inseparable from the study of **culture**, since culture emerges from the interaction between internal and external (material and social) structures, within the historical context of activities. Culture, as a history of material artefacts and social practices, also shape cognitive processes distributed over agents and their environments.

DC differs from other approaches in that it is committed to two related theoretical principles. The first principle concerns the **boundaries of the unit of analysis** for cognition (further discussed in Section 2.3). As discussed by Hollan et al. (2000), the activities of a group cannot be fully understood from the individual’s perspective. Therefore, cognitive processes are considered on the basis of the functional relationships of elements that participate in the process, and the process itself is then delimited by the functional relationships between these elements. The second principle concerns **the range of mechanisms** that may be assumed to participate in cognitive processes. Not all mechanisms take place on the ‘inside’, instead there is a “rich interaction between internal processes, the manipulation of objects, and the traffic in representation” (i.e., propagation and transformation of representations). Applying these principles when observing activities, at least three kinds of distribution of cognitive processes become apparent:
1. Cognitive processes may be distributed across the members of a social group.
2. The operation of the cognitive system involves coordination between internal and external (material or environmental) structure.
3. Processes may be distributed through time in such a way that the products of earlier events can transform the nature of later events.

These kinds of distributions are illustrated, for instance, in Hutchins’ (1995b) analysis of a memory task in a cockpit (remembrance of speed; for further details, see Hutchins, 1995b). Amongst the many details of this study, we note that within this system there are different kinds of representations, or media, of which some are observable (e.g., instruments, booklets, verbal exchanges among crew members, etc.) and others are non-observable (e.g., the memories of the pilots). An observable representation in the performance of the memory task is a speed card booklet, which is posted where it can be seen easily. Such an artefact is a relatively permanent representation, durable over time, which provides a long-term memory. Spoken representations, on the other hand, like speed call outs, only endure in their production. By use of such representations, the pilots create a distribution across social space and of access to information in the system. The way representations are propagated across these media shows that memory, as observed in the cockpit, is a continual interaction with the world during which both internal and external representations are continually reconstructed. The different kinds of representations that are used are brought into coordination with one another, which provides a representational state that will be coordinated with other representations later on. The entire process is called ‘a cockpit system’s memory’ as it consists of the creation of representational states that are used, e.g., to organize subsequent activities.

The way cognitive processes are distributed has been further analysed in a great number of studies on socio-technical systems, varying from ship navigation (Hutchins, 1995a), software development (Flor & Hutchins, 1991), airline cockpits (Hutchins, 1995b; Hutchins & Klausen, 1996), underground transportation systems (Garbis, 2000), organisational memory (Ackerman & Halverson, 1998), to design (Perry et al., 2003; Spinelli et al., 2005; see also Woods, 1998).

However, this framework has also received some criticism. For instance, it has been accused of blurring the distinction between humans and the non-cognitive tools they use (cf. the next section, concerning the bounds of cognition). Furthermore, according to Nardi (1996), DC is problematic in that it considers humans and artefacts as equal. She draws a parallel between cognitive science and distributed cognition. Thus, according to her opinion, distributed cognition views people and things as conceptually equivalent; people and artifacts are ‘agents’ in a system. This is similar to traditional cognitive science, except that the scope of the system has been widened to include a collaborating set of artifacts and people rather than the narrow ‘man-machine’ dyad of cognitive science...
each node in a system as an ‘agent’...leads to a problematic view of cognition. We find in distributed cognition the somewhat illogical notion that artifacts are cognizing entities. Flor and Hutchins (1991) speak of ‘the propagation of knowledge between different individuals and artifacts’. But an artefact cannot know anything; it serves as a medium of knowledge for a human. A human may act on a piece of knowledge...according to socially or personally defined motives. A machine’s use of information is always programmatic...The activity theory notion of artifacts as mediations of cognition seems a more reasoned way to discuss relations between artifacts and people. (p. 86-87)

When considering isolated statements like ‘the propagation of knowledge between different individuals and artifacts’, it is perhaps possible to draw the conclusion that ‘people and artefacts are considered equal’, but speaking of ‘propagation of knowledge’ and ‘people and artefacts as nodes in a system’ does not turn artefacts into ‘cognising entities’. Whilst artefacts in a cognitive system propagate information, and transform representations of information, they do not have to ‘know’ anything in order to do so. Somewhat ironically, Nardi’s critique stems from a comparative discussion of different approaches, with a focus on context, while she takes a few statements on DC out of their context and concludes the equality of people and artefacts. According to Hutchins (personal communication), the idea of equalising artefacts and humans is false – they are not considered equal. Instead, considering people and artefacts as nodes within a system is to use the classical cognitive science frame on a system level, rather than the level of individual cognition. As he himself explains (1995a, p. 49):

I will attempt to apply the principal metaphor of cognitive science–cognition as computation–to the operation of this system [of ship navigation]. In so doing I do not make any special commitment to the nature of the computations that are going on inside individuals except to say that whatever happens there is part of a larger computational system. But I do believe that the computation observed in the activity of the larger system can be described in the way cognition has been traditionally described—that is, as computation realized through the creation, transformation, and propagation of representational states.

It might be a source of confusion though, to speak of cognition as computation and propagation of knowledge, and, at the same time use the frame of classical cognitive science to the operation of cognitive systems. The main concern in classical cognitive science is representations of knowledge, and people are considered equal to computers, being ‘computing devices’ who operate upon their representations. In this view, computers operating upon representations are assumed to be knowledgeable, like people. Talking of “propagation of knowledge between people and artefacts” might therefore imply that artefacts are ‘cognising entities’. But, the frame of classical cognitive science should not be confused with the notion of propagation of representations/knowledge, as used in DC. The criticism posed by Nardi therefore seems to be a failure in recognising the way the cognitive science framework is intentionally applied to a system level, and that DC, as well as activity theory (which Nardi strongly advocates), does differentiate between people and artefacts. Others, however, have noticed the difference (e.g., Clark, 1999b; Raeithel, 1992; Rogers & Ellis, 1994). Clark (ibid.), for

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8 The comparison includes distributed cognition, situated action, and activity theory.
instance, describes a typical navigation team, and the complex ways in which representations and computations are propagated through an “extended web of crew and artefacts”, and he also notes that it is shown “in convincing detail, just how genuinely distributed (between agents) and reshaped (by the use of artefacts, spatial layout, and simple event-response routines) the ship navigation task has become” (p. 510).

To summarize this section, distributed cognition (as formulated by Hutchins), focuses on cognition at the system level rather than the level of individual cognition. Its primary unit of analysis is the complex socio-technical system, with focus on the ways representations are propagated through and transformed within the system. Such processes include distribution of cognition across members of a group, coordination between internal and external structures, and distribution through time. The observation of such cognitive processes is made possible by moving the boundaries of the unit of analysis, from individuals to the larger system of people and the artefacts they use when performing a task.

### 2.3 The bounds of cognition

The rise of the situated cognition paradigm has led to debates concerning the bounds of cognition. It is commonly agreed that artefacts change our cognitive processes, and a more recent question concerns whether artefacts also extend cognition beyond what is biologically and physically given. The question of where exactly the boundary between a cognitive system and its environment should be drawn is as old as the study of the mind itself. Polanyi (1964) and Bateson (1972) illustrated the question with the now classical example of a blind man using a stick, and asked what the bounds of the blind man’s system are. More specifically, does it include the stick itself, or not? Another classical example, the knot in a handkerchief, comes from Vygotsky (1978) who argued that the knot serves as a reminder that changes the psychological structure of the memory process, and it extends the operation of memory “beyond the biological dimensions of the human nervous system” (ibid., p. 39). The knot transforms remembering into an external activity in which we remember actively with the help of signs, i.e., we construct the process of memorizing by forcing an external object to remind us of something (Vygotsky, 1960/1977) (further discussed in Chapter 3). The question of where the boundary should be drawn was not much considered during the first decades of cognitive science, which paid relatively little attention to the interaction between agent and environment. With the growing awareness and emphasis on the close coupling between agent and environment, and its central role in cognitive processes, the question of the bounds of cognition is going through a certain revival in theories of situated, embodied, and distributed cognition.

While the term ‘cognitive’ has traditionally been used mostly for internal processing, in the 1990s it started to appear in expressions such as

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9 This section appeared in similar form in Susi, Lindblom & Ziemke (2003).
‘cognitive tool’ and ‘cognitive artefact’ (further discussed in Section 2.5). We have also seen arguments that cognition extends into the world and that the boundaries of cognition and the body are changeable (Clark, 1997; Smitsman, 1997; Hirose, 2002; Hutchins 1995; Wilson, 2004). Cognition as an extended phenomenon has been considered under different labels, such as cognitive systems (Hutchins, 1995a) or joint cognitive systems (Hollnagel & Woods, 2005) (discussed in the previous section), extended (or wide) computationalism (Wilson, 2004), and extended mind thesis (Clark & Chalmers, 1998). Others consider this a “radical view of tool use” and argue that it blurs the distinction between cognitive agents and the non-cognitive tools they use (Adams & Aizawa, 2001; Nardi, 1996; Neuman & Bekerman, 2000). Adams and Aizawa (2001), for instance, have formulated a detailed critique against several theories they consider go too far in blurring that distinction, i.e., cases in which cognitive processes are considered to extend into the physical world beyond the bounds of the individual (e.g., Clark and Chalmers, 1998; Dennett, 1996; Donald, 1991; Hutchins, 1995a). Adams and Aizawa defend a common sense view of cognition, or intracranialism, and in their view cognition is “restricted to the confines of our brains” (p. 44). More precisely, they argue that

in all actual cases of human tool use brain-bound cognitive processes interact with non-cognitive processes in the extracranial world [and] given what we know about the human brain and cognition, the chances that some tool in our hands would have the cognitive properties our brains do is rather unlikely. (p. 46, 47)

However, Adams and Aizawa (2001), and others who argue along similar lines, may be fighting windmills since most of the views they consider ‘radical’ may not be radical at all – in fact, they are highly compatible with the ‘common sense’ view they defend.

It is commonly agreed that people use external resources or structures, such as calculators, road signs, notes, calendars, computers, pen and paper, and even other people, as a way of overcoming our cognitive limitations. In other words, as formulated by Clark (1997, p. 68), we “call on external resources to perform specific computational tasks”10. However, external structures are not used merely for overcoming our cognitive limitations. Instead, as Wilson (2004) argues, in doing so we can take advantage of external structures and our ability to control ourselves (a point also made by Vygotsky, further discussed in Chapter 3). As Wilson further argues, “the mind extends itself beyond the purely internal capacities of the brain by engaging with, exploiting, and manipulating parts of its structured environment” (p. 195). Similarly, Polanyi (1969) has expressed that when

...we use a tool or a probe and, above all, when we use language in speech, reading, or writing, we extend our bodily equipment and become more effective and more intelligent beings. All human thought comes into existence by grasping the

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10 Adams and Aizawa, as well as several of the authors they criticise, refer to cognitive and brain processes as ‘computational’. The term itself may be controversial (cf., for instance, Clark, 1997), but the discussion here is relatively independent of whether ‘computation’ is the appropriate term in all cases.
meaning and mastering the use of language. Little of our mind lives in our natural body; a truly human intellect dwells in us only when our lips shape words and our eyes read print. (p. 160)

As an example of using external resources, consider, for instance, the use of Scrabble tiles (Clark, 1997; Clark & Chalmers, 1998; Kirsh, 1995b; Kirsh & Maglio, 1994). As described by Clark, the tiles are physically ordered and re-ordered during play, thereby prompting our own on-line neural resources. We manipulate the tiles externally and thereby create a variety of fragmentary inputs (new letter strings) capable of prompting the recall of whole words from the pattern-completing resource. It seems that our own biological resources do not easily provide for this kind of manipulation and might thus be considered as a set of operational capacities, which emerge from the interaction between brain and world. In other words, through the flexible use of environmental resources we enhance or augment our own cognitive abilities, we use them as scaffolds. The Scrabble tiles, for instance, scaffold our thinking, and, thus in a very real sense it can be said that “the re-arrangement of tiles on the tray is not part of action; it is part of thought” (Clark & Chalmers, 1998). Consider a second example, provided by Clark (1999a):

Most of us, armed with pen and paper, can, for example, solve multiplication problems that would baffle our unaided brains. In so doing we create external symbols (numerical inscriptions) and use external storage and manipulation so as to reduce the complex problem to a sequence of simpler, pattern-completing steps that we already command. On this model, then, it is the combination of our biological computational profile with the fundamentally different properties of a structured, symbolic, external resource that is a key source of our peculiar brand of cognitive success. The external environment, actively structured by us, becomes a source of cognition–enhancing ‘wideware’ – external items (devices, media, notations) that scaffold and complement (but usually do not replicate) biological modes of computation and processing, creating extended cognitive systems whose computational profiles are quite different from those of the isolated brain. (p. 349)

The general point in these examples, that cognitive processes can be complemented, augmented and transformed by environmental scaffolds, in particular by the use of tools, conforms to Adams and Aizawa’s view. However, Adams and Aizawa oppose ideas of the environment as a source of cognition, and the notion of agent and environment as an extended cognitive system, or ‘coupled system’ as Clark and Chalmers (1998) call it. In their view, “common sense has it that our cognitive faculties, restricted to the confines of our brains, can be aided in any manner of ways, by cleverly designed non-cognitive tools” (p. 44). So, they agree that internal cognitive processes coupled with the environment can augment those processes, but they maintain that “the mere causal coupling of some process with a broader environment does not...extend that process into the broader environment” (p. 56). Adams and Aizawa’s opinion about non-cognitive tools is in fact very similar to, e.g., Norman’s view on cognitive tools (cf. Section 2.5). According to Norman, the notion of ‘cognitive tools’ refers to tools that enhance our cognitive abilities, but the tool itself is not considered to have any cognitive processes or abilities with which humans are endowed. Considering processes as extending into the broader environment is not the same as
saying that the environment, or some part of it, actually comes to have human-like cognitive processes or capacities itself. Actually, what seems to be two opposite views, cognitive vs. non-cognitive tools, turns out to be a use of different terminology, yet referring to the same thing. However, Clark and Chalmers (1998), who refer to their view of the extended mind as an “active externalism”\(^\text{11}\), argue that this is not just a matter of terminology, but more a matter of methodology:

...in seeing cognition as extended one is not merely making a terminological decision; it makes a significant difference to the methodology of scientific investigation. In effect, explanatory methods that might once have been thought appropriate only for the analysis of ‘inner’ processes are now being adapted for the study of the outer, and there is promise that our understanding will become richer for it (ibid., p.10)

An example of extending the application of traditional cognitive scientific methods and terminology from ‘inner’ to ‘outer’ processes is Hutchins’ (1995) work on distributed cognition (cf. Section 2.2). Hutchins approach is concerned with ‘high-level’ cognition, such as team performance in ship navigation, i.e., inter-individual rather than intra-individual cognition. Analysing ship navigation, Hutchins (1995a) showed how multiple embodied biological brains combine with tools (such as sextants and alidades), and media (such as maps and charts) during performance. The artefacts allow the human users “to do the tasks that need to be done while doing the kinds of things people are good at: recognizing patterns, modelling simple dynamics of the world, and manipulating objects in the environment” (ibid., p. 155). In this analysis Hutchins, as he points out, deliberately applied “the principal metaphor of cognitive science – cognition as computation – to the operation of this system” (p. 49). However, Adams and Aizawa argue that in doing so, Hutchins “threatens to depart from common sense, toward Dennett’s radical transcranial cognition”, because “[i]f cognition is simply computation over representational states, and if one’s tools, such as paper and pencil, form or contain representations, then one has a case for the radical view that, in at least some cases of tool use, cognition extends beyond the boundary of the brain” (p. 46). Adams and Aizawa further argue that

Hutchins is studying what might best be thought of as naturally occurring computation rather than cognition. In the first place, it appears that a principal source of difficulty for Hutchins’ analysis is that it is likely that as a matter of contingent fact, the kinds of computational processes we find operating over external representations, such as marks on a piece of paper, readings of meters and dials, indicator lights, warning lights, and so forth, will turn out to differ from the kinds of computational processes that we find operating over representations in brains. Compare the intracranial computation of the product of 347 and 957 from the computation of this product with pencil and paper. We may assume that there are computational processes at work in both cases, but that these computational processes are different. In particular, the internal processes are cognitive computational processes, where only some of the computational processes in the transcranial cases are cognitive. In particular, it will be only the

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\(^\text{11}\) To be distinguished from the “passive” externalism of, e.g., Putnam (1975) and Burge (1979)
internal portions of the transcranial computation that turn out to be cognitive. So we should note that, in the purely intracranial case, there would be no processing corresponding to the visual processing of the marks on pencil and paper found in the transcranial computation. Nor would the intracranial computation involve an analogue of the motor manipulations of the pencil used in the transcranial computation. Nor would the intracranial process involve anything like the process that rubs bits of graphite onto a sheet of paper, although it is not known in any serious detail how the internal processing works in these diverse cases, we can reasonably maintain that they in fact are not all the same. (p. 59)

Obviously, then, according to Adams and Aizawa (2001), the processes taking place within the head and those taking place outside it, are two quite different procedures in which different sets of cognitive capacities are deployed. Furthermore, the causal processes in the brain are nothing like the causal processes of generating marks on a paper, so “[w]hat could be more obvious than that the processes are causally distinct?” (ibid., p. 43, 44). As discussed in the previous section (2.2), similar critique has been raised by Nardi (1996), who argues that distributed cognition views artefacts as cognising entities, when in fact an artefact cannot know anything, but instead serves as a medium of knowledge for humans. These observations are clearly commonsensical and, indeed, it would be absurd to argue otherwise.

While Adams and Aizawa, as well as Nardi, may very well be right about the differences in human and machine computation, their critique is nevertheless misguided as none of the criticised authors actually deny those differences. Clark, for instance, referred to biological computation and external resources as “fundamentally different” (cf. above quote). Furthermore, he made it clear that he views the environment as a “source of cognition”, but only in the sense that it complements, rather than replicates, biological computation and processing. Similarly, Hutchins explicitly pointed out that he uses the notion of “cognition as computation” as a metaphor in describing distributed cognitive systems, and he never denied the differences between internal cognitive processes and external non-cognitive processes. Hence, much of the “radical view of tool use” turns out to be less radical than it might seem at first.

The same applies to Adams and Aizawa’s critique of Donald (1991), whose view they consider “in many respects...the same as Dennett’s and Clark and Chalmers” (p. 45). However, it is not clear in what way these views are ‘the same’. Donald’s theory is concerned with ‘exograms’, or external representations, and their impact on human evolution. In Donald’s (1991) view, there have been three evolutionary transitions that may have caused changes in the cognitive architecture, and “[t]he existence of exograms eventually changed the role of biological memory in several ways”. While the first two evolutionary transitions increased the load on biological memory, “the final step in this tremendous cognitive expansion might have reduced the load on some aspects of biological memory, by gradually shifting many storage tasks onto the newly developed ESS [external symbol storage]” (Donald, 1991, p. 320). Adams and Aizawa argue that these exograms are considered as “part of the human cognitive architecture” (p. 58), and thus
Donald implicitly refers to psychological laws of human memory that will not generally hold for external memory storage. However, in Donald’s description the biological and the external are two quite different things. While engrams refer to single entries in the biological memory system, exograms refer to single entries in the ESS, and are considered external memory records of ideas (Donald, 1991). Even though both exograms and engrams are described in similar terms, exograms do not become biological, not even ‘implicitly’. Exograms and engrams do not, then, make the case for Adams and Aizawa. Interestingly, Donald notes that a symbolic information environment, freeing us from wholly depending on biological memory, requires interpretation since “exograms and engrams are both interpretable only by the individual mind, which must provide the referential basis for understanding the memory record” (Donald, 1991, p. 315). However, systems of exogram storage are much more flexible than engrams, and a “cognitive system containing exograms will have very different memory properties from a purely biological system”, which is in line with Clark’s reasoning that cognitive systems of biological brains and external resources perform very differently than just the naked brain alone does (Clark, 1997). Still, neither Donald nor Clark argues that hooking the biological system to external resources transforms the external into biologically cognitive entities. In fact, both are careful to point out the fundamental differences.

Bateson (1972), in the example of the blind man using a stick, argued that questions concerning whether a mental system is bounded by skin or skull, whether artefacts should be included or not, and so on, are in fact “nonsense questions”. Instead, a far more important question should be what one seeks to understand, and therefore what should be considered the unit of analysis. Similarly, Perkins (1993), from a distributed cognition perspective, questions whether it really matters if ideas lie inside or outside the individual’s head. Instead, in Perkins’s view, it is a matter of principle. Function (information flow and its accessibility), we are told, is of greater importance than locus, that is, exactly where information is located. The problem of drawing a firm line for the mental system is nicely illustrated by Polanyi (1964), who argued:

> [t]he way we use a hammer or a blind man uses his stick, shows in fact that in both cases we shift outwards the points at which we make contact with the things that we observe as objects outside ourselves. While we rely on a tool or a probe, these are not handled as external objects...We pour ourselves out into them and assimilate them as parts of our own existence. (p. 59)

When using a hammer or a stick, then, awareness of the object itself is lost, and the person is only aware of whatever the hammer strikes, or the cane touches, and if everything is going well he is not even aware of that since the object becomes embodied by him (cf. Hirose, 2002). Similarly, Bateson describes the blind man’s stick as “a pathway along which transforms of difference are being transmitted”, and “the way to delineate the system is to draw the limiting line in such a way that you do not cut any of these pathways in ways which leave things inexplicable” (p. 465). Subsequently, the boundaries of cognition, as well as the appropriate units of analysis in the study of cognition, depend on what we want to explain. Human activities
cannot, for the most part, be studied without considering things like the artefacts we use. Likewise, artefacts cannot be studied apart from their use since in itself a tool is nothing (Ingold, 2000). Hence, it is only natural for cognitive scientists interested in situated, embodied, and distributed cognition to choose as their units of analysis cognitive agents in situ, i.e., embedded in their environments. Subsequently, the ‘bounds-of-cognition’ discussion is not really an issue of primary interest, and should be put aside since the unit of analysis depends on what we want to understand. Consequently, whether or not such units should be referred to as extended cognitive systems, and whether or not the tools involved should be referred to as cognitive tools, are only secondary questions.

2.4. Artefacts, tools, and tool use

The terms artefact and tools have thus far not been considered in much detail. In this section I turn to some definitions and categorisations, a few specifically artefact/tool related concepts, and a recent theory of cognition and tool use.

At first glance, the concepts of artefact and tool may seem easy to grasp, but it has also been said that ‘only that which has no history is definable’ (Sheehan, 1991). Artefacts/tools, generally speaking, do have histories of development and use, and the current use of such objects may not be their original use, and thus they are not easily understood or defined, and their definition has proven problematic. In what might be called folk-psychological terms, tools have often been defined as ‘man-made’ (a persistent definition despite the well-known fact that man is not the only species to make tools; cf. Chapter 4). Tools are usually thought of as work related objects that are hand-held or operated by hand. Just as often, however, the same tools are described as man-made artefacts. Yet, not all tools are made by man; naturally occurring objects may also be used as tools. A stone, e.g., can be used for pounding (like a hammer), but few would probably consider the stone an artefact. It also seems that there is fine line defining what behaviours should or should not count as tool use. For instance, with respect to behaviour, most of us would describe the bodily movements involved in digging with a spade as ‘tool behaviour’. However, if someone were to replicate the same bodily movements for the purpose of judging if the spade is suitable for a certain kind of soil, the question arises whether that is also tool behaviour. This identifies some problems, generally encountered in literature concerning tools and cognition, and other related issues; how to distinguish and define tools and artefacts, how to categorise objects, what behaviours count as tool use, etc.

2.4.1 What are artefacts and tools?

A great number of definitions for artefacts and tools have been suggested and various classifications have been made. These definitions range from rather narrow and precise ones, to less clear-cut and all-encompassing ones. While some are rather similar, others are more contradictive. Perhaps the most precise and uniform definitions are those found in dictionaries. Artefact has been defined as:

27
- a product of human art and workmanship. 2) (archaeol.) a product of prehistoric or aboriginal workmanship as distinguished from a similar object naturally occurring (The Concise Oxford dictionary, 1995)
- product of human craftsmanship, esp. a simple tool or ornament (New English dictionary and Thesaurus, 1994)
- something created by humans usually for a practical purpose; especially: an object remaining from a particular period <caves containing prehistoric artifacts> (Merriam-Webster OnLine)
- (archaeol.) Object, as palaeolithic flint, made by human workmanship (The Oxford Illustrated Dictionary, 1962/1975)

The same dictionaries define tool as:

- any device or implement used to carry out mechanical functions whether manually or by a machine 2) a thing used in an occupation or pursuit (The Concise Oxford dictionary, 1995)
- an implement that is used by hand; a means for achieving any purpose (New English dictionary and Thesaurus, 1994)
- 1 a: a handheld device that aids in accomplishing a task b (1): the cutting or shaping part in a machine or machine tool (2): a machine for shaping metal 2 a: something (as an instrument or apparatus) used in performing an operation or necessary in the practice of a vocation or profession <a scholar’s books are his tools> b: a means to an end <a book’s cover can be a marketing tool> (Merriam-Webster OnLine)
- implement for working upon something, usu. one held in and operated by hand, but also including simple machines, as lathe; (cutting-part of) machine-tool; anything used in performing some operation or in any occupation or pursuit (The Oxford Illustrated Dictionary, 1962/1975)

According to these definitions, an artefact might be described first of all as something produced by humans, or a product of workmanship. Secondly, the term artefact denotes a prehistorical remnant. Either way, these explanations point at ‘something that has been produced by man’. A tool seems to have a ‘double’ definition: on the one hand, tool is restricted to hand-held devices or something that is manually operated. On the other hand, there are no limitations as to what might constitute a tool since it can be ‘anything used in any pursuit’. Of course, dictionary definitions, such as these, are adjusted to cover a concept in general, rather than to be used in a specific domain. However, at the same time such definitions become too narrow (e.g., hand-held), or too wide, including everything, and end up defining nothing. Hence, dictionary definitions are not as informative as they might seem at first glance. These definitions also exclude the ‘tool of tools’, viz., the hand, a view held already by Aristotle (Jouffroy, 1993). In Russian cultural-historical psychology, Luria and colleagues considered language as the ‘tool of tools’ (Cole & Engeström, 1993). Language has also been called ‘the ultimate artefact’ (Clark, 1997). Language and other linguistic
tools/artefacts, such as writing\textsuperscript{12}, are also excluded from dictionary definitions. It is commonly accepted that language is an artefact and (or) a tool (e.g., Cole, 1996; Gauker, 1990; Goody, 1997; Wartofsky, 1979). However, in terms of the above definitions, language could hardly be considered an artefact since it is neither a result of workmanship, nor a prehistorical remnant. Neither could language be seen as a tool, since it is not 'a hand-held device', even though it may be 'a means to an end'. In addition to these problems, the definitions also exclude the vast category of (internal) cognitive artefacts, such as mnemonic techniques, concepts, heuristics, etc.

Numerous further definitions of these terms are found in scientific literature. Here some illustrative examples may suffice. Ingold (1993b), for instance, describes an artefact as an "object shaped to some pre-existent conception of form", while a tool "in the most general sense, is an object that extends the capacity of an agent to operate within a given environment (p. 433). Artefacts have also been described as things that result “from the shaping of naturally given raw material to a preconceived cultural standard” (Goodenough, 1981, cited in Ingold, 1993a, p. 340). In Hendriks-Jansen (1996) we find a description common to many writings, in which he states that the physical environment (of humans) is a "cultural environment composed of artifacts and tools" (p. 133), both of which are ‘man-made’. He further maintains that we "communicate through language and manipulate tools and artefacts" (p. 255), but he also mentions cultural and linguistic artefacts. Hence, it is unclear whether language is separated from other artefacts and tools, and it remains undefined what an artefact or a tool is, besides being ‘man-made’. Hence, these terms are rather like the folk psychological concepts whose meaning can be understood intuitively but which do not provide any scientific explanation as to what they are, even though Hendriks-Jansen himself opposes describing surface phenomena in folk psychological terms. Artefacts have also been described as a mixture of mechanics and psychology which makes artefacts a strange category (Pinker, 1997). According to Pinker (1997, p. 314) “we understand birds and plants in terms of their innards...we cut them open and put bits under a microscope”, but artefacts cannot be defined by shape or constitution, instead another kind of explanation is needed. Pinker describes an artefact as “an object suitable for attaining some end that a person intends to be used for attaining that end” (p. 327). Artefacts thus depend on human intention, making them subject to interpretation. Consequently, we need “a statement of the function the object is intended to perform” since artefacts can only be defined by "what someone, somewhere, wants them to do" (p. 328). A chair, for instance, is a chair because it has been designed to hold people up, while a naturally occurring object is not a chair until someone decides to treat it as one.

Mantovani (1996) considers artefacts, in a wide sense, as including the instruments required for physical operations, as well as the social norms

\textsuperscript{12} For further discussion on oral and written language, see, e.g., Ong (1982).
\textsuperscript{13} For a discussion on the distinction between artefacts and naturally occurring objects, see, e.g., Losonsky (1990)
established in our social institutions. Hence, he identifies two categories of artefacts: a) instrument-artefacts (or tool-artefacts), that take on a physical body and are used to perform a task as well as being inseparable from the task they are intended for, and b) concept-artefacts that formulate the basic principles of a culture, e.g., theories. However, Mantovani also points out that the distinction between the two is not clear or solid since “in all cultures tools and norms merge, for the simple reason that tools serve to perform tasks, which in turn are performed in order to carry out more ample projects which are selected according to values, principles and norms which, again in turn, are formulated starting from the practical availability of proper tools” (p. 64). Consequently, in this case artefacts basically fall into two classes, material and mental, which indeed is a classification in ‘a wide sense’.

2.4.2 Classifications and tool behaviour

In contrast to the definitions above, Wartofsky (1979) describes in much more sweeping terms that a tool could practically “be any artifact created for the purpose of successful production and reproduction of the means of existence” (p. 201). However, Wartofsky also proposes a three level classification of artefacts; primary, secondary, and tertiary artefacts. Primary artefacts are ones used directly in production, such as axes, needles, bowls, etc. Secondary artefacts are (internal and external) representations of primary artefacts, and they are created and used “in the preservation and transmission of the acquired skills or modes of action or praxis by which this production is carried out” (p. 202). As such, secondary artefacts are representations of these modes of action. ‘Representing a mode of action’ also means that these artefacts are related to conventions, as in rules and norms. Tertiary artefacts are ‘imaginary’ artefacts, such as art or ‘free’ play or game activity. Such artefacts have ‘lost’ their original role of representation. They have become “abstracted from their use in productive praxis” and from their “direct representational function”. Therefore they no longer appear directly practical. Cole (1996) proposes that words and writing instruments be included in the category of primary artefacts. Writing instruments could be considered primary artefacts, but in Wartofsky’s view, however, words are oral/linguistic representations, i.e., secondary artefacts. Perhaps more importantly, Cole suggests a generalisation of Wartofsky’s conception by “linking the notion of artefact on the one hand to notions of schemas and scripts and on the other hand to notions of context, mediation, and activity” (1996, p. 122). Such a generalisation directs attention to artefacts as “the linchpin of cultural mediation” (ibid.), and to the ways artefacts are part of joint human activities.

14 Accordingly, Engeström (1987) considers Vygotsky’s psychological tools as secondary artefacts.

15 As discussed by Cole, the notion of schemas and artefact mediation might be conceived problematic since schemas in cultural psychology, for the most part, are taken to be internal mental structures of “culture as meanings, which come unmoored from their material instantiation” (p. 128). However, schemas may refer to conventions, materialised practices, and internal structures that are both inside and outside the head (with reference to Bartlett), in which case schema and artefact mediation coincide very well. For further discussion on Bartlett, schema theory, and its accordance with the situated/embodied view on cognition, see, e.g., Kashima (2000) and Saito (1996).
From an activity theoretical perspective, Engeström (1990) has elaborated Wartofsky’s categorisation, and added another class of artefacts. Primary artefacts are now termed what-artefacts, and they are basically the external entities used in an activity such as documents and marks on computer screen (the examples used here are from Engeström’s study in a health care centre). He further differentiates between two types of secondary artefacts: how-artefacts and why-artefacts.

- **How-artefacts** are specific types of artefacts (routines, procedures, etc.) that tell us how to handle a certain object (of an activity; in this case a patient) with a corresponding primary artefact. How-artefacts can be both external and internal. For instance, routines for computer use may be found in a written form, while people also have their personal internal versions of them. These how-artefacts, then, tell how to handle a corresponding primary artefact, for instance, routines for how to handle computer data on a patient.

- **Why-artefacts** are general types of artefacts that inform us why the object of an activity behaves the way it does (e.g., a patient), which justifies the selection of some specific primary artefact. These why-artefacts are internal, mental explanatory models, but they can also be (although not always easily identified) externalised in words, gestures, etc. As described in Engeström’s health care centre study, the explanatory model (of a patient’s illness) held by a doctor, emerges from his/her expectations and preconceptions, and initial data (e.g., the patient’s medical record). On the basis of the first impression and the patient’s own account, the doctor constructs a meaningful pattern and “makes sense of the accounts with the help of some more or less consciously held explanatory model of illness” (Engeström, 1990, p. 183). The meaningful pattern is subsequently transformed into a diagnosis. In other words, the doctor forms a hypothesis concerning the patient’s illness, which is accomplished through examination and testing. Hence, the hypothesis justifies a certain kind of examination, which, in turn, depends on the doctor’s knowledge and mastery of the procedures for certain examinations and tests.

Engeström (1990) also identifies tertiary artefacts, which he terms where-to-artefacts. These are artefacts that “go beyond the explanatory or diagnostic ‘why’ function” (p. 194), and as such they are close to Wartofsky’s imaginary (tertiary) artefacts. Where-to artefacts can be described as projections into the future, or a vision of what will follow from, e.g., demanding changes in tools. The primary psychological importance of where-to-artefacts, we are told, may be their power of motivation; an analysis and vision of the future is important for motivating acceptance and implementation of new tools. The different types and categories of artefacts are summarised in Table 2.
Table 1. Summary of artefact categorisations by Wartofsky (1979) and Engeström (1990).

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<tr>
<th>Tertiary artefacts</th>
<th>Where-to’ artefacts</th>
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<tr>
<td>Imaginary artefacts</td>
<td>Vision of future (consequences of new tools in organisation)</td>
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<table>
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<th>Secondary artefacts</th>
<th>Why’ artefacts</th>
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<tbody>
<tr>
<td>Internal and external representations of primary artefacts</td>
<td>General type, explanatory model of why object behaves as it does. Justifies selection of certain primary artefact, e.g., hypothesis – examination</td>
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</table>

<table>
<thead>
<tr>
<th>Primary artefacts</th>
<th>How’ artefacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Directly used in production</td>
<td>Specific type that tells how to handle object with corresponding primary artefact, e.g., routines for computer use – computer data on patient</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Primary artefacts</th>
<th>What’ artefacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Directly used in production</td>
<td>External physical entities (marks on computer screen, documents)</td>
</tr>
</tbody>
</table>

Another classification of artefacts is provided by Mitcham (1994), as seen from a technological perspective, i.e., in the sense of considering technology in terms of objects. As described by Mitcham, “[a]rtifacts – material objects such as tools, machines and consumer products – are what most readily come to mind when the word ‘technology’ is mentioned”. Mitcham classifies artefacts as follows:

- **Clothes** – artifacts for covering the human body, both utilitarian and decorative.
- **Utensils** – e.g., baskets, pots, dishes, spoons; storage containers and instruments of the hearth and home.
- **Structures** – e.g., houses and other stationary artifacts within which human activities take place.
- **Apparatus** – e.g., dye vats, brick kilns, containers for some physical or chemical process initiated and controlled by humans.
- **Utilities** – e.g., paths, roads, reservoirs, electric power networks.
- **Tools** – instruments operated manually that act to move or transform the material world, usually outside the home (contrast household utensils); typically, implements a worker uses to perform work, although there are certainly tools of communication and scholarship (paper and pen) as such.
- **Machines** – tools that do not require human energy input because they have an external source of power (wind, water, steam, electricity, etc.) but do require human direction; devices that operate, under human direction, to perform work.
- **Automata** or automated/cybernetic machines – machines that require neither human energy input nor immediate human direction. Automated devices take part of their energy output and recycle it back onto the device itself as a form of control. (One common example is a thermostatically controlled heater, where some small fraction of the heat output is used to operate a thermocouple that in turn regulates the heat level.) (p. 161)

The tools in this list constitute a category subordinated to artefacts, even though the list includes artefacts as well as tools. While the list is formulated
from a technological point of view, the categorisation of artefacts and tools is in accordance with the previous dictionary definitions and the distinction between the two: artefacts are material objects produced by humans, and tools are manually operated objects. There is one exception (or addition) though. In the category of tools, Mitcham recognises tools for communication. To this list, Mitcham also adds three other possible types of technology as objects:

- those already hinted at under tools, that is, tools of doing or performing (letters, numbers, musical instruments).
- ... artifacts that are not meant to be used in the normal sense but are only contemplated or worshiped (or more accurately, used as a means of worship), that is, objects of art or religion.
- Toys, or artifacts of play and games. (p. 162)

It should be noted that Mitcham does not consider these categories to be exclusive or complete, and they can overlap.

The descriptions and views on artefacts and tools mentioned so far, are in no way exhaustive, but they suffice to point out that definitions vary and that there does not seem to be any one uniform or coherent definition of the two concepts. As discussed in previous sections, a situated cognition perspective, generally speaking, does not consider artefacts, tools, and their use as isolated entities, devoid of any relation to, for instance, the situation at hand, or cultural aspects. This is not to say that all the above descriptions are non-contextual, but quite many definitions place the core of what a tool (or artefact) is, within the tool itself. However, as argued by Ingold (1993a), for instance, the quality of being an artefact or a tool is not inherent in the object itself since a tool in itself is nothing. An object, we are told, becomes a tool when conjoined with technique, i.e., the properties of skilled subjects. Similarly, an object becomes an artefact when conjoined with an intended project, and “both the instrumentality and the artefactuality of objects are conditional upon the situational contexts of their engagement in practical activity, and as objects endure over time, having histories of such engagement, so their status can change” (p. 341). Similar ideas were already expressed by Butler (1912) who wrote that

[a] tool is anything whatsoever which is used by an intelligent being for realising its object. The idea of a desired end is inseparable from that of a tool. The very essence of a tool is the being an instrument for the achievement of a purpose. We say that a man is the tool of another, meaning that he is being used for the furtherance of that other’s ends...Strictly speaking nothing is a tool unless during actual use...Thus a stone may be picked up and used to hammer a nail with: the stone is not a tool until picked up with an eye to use; it is a tool as soon as this happens – if thrown away immediately the nail has been driven home the stone is a tool no longer. We see, therefore, matter alternating between a toolish or organic state and an untoolish or inorganic...The simplest tool I can think of is a piece of gravel used for making a road. Nothing is done to it, it owes its being a tool simply to the fact that it subserves a purpose...even a piece of gravel found in situ and left there untouched, provided it is so left because it was deemed suitable for a road which was designed to pass over this spot, would become a tool in virtue of the
recognition of its utility, while a similar piece of gravel a yard off on either side the proposed road would not be a tool. The essence of a ‘tool’, therefore, lies in something outside the tool itself. It is not in the head of the hammer, nor in the handle, nor in the combination of the two that the essence of mechanical characteristics exists, but in the recognition of its utility, and in the forces directed through it in virtue of this recognition. (p. 121-122)

The ‘toolness’ of a tool, then, according to Butler, lies in its use for achieving a purpose and the recognition of its utility, and an object becomes a tool only during actual use in a certain situation. Similarly, Ingold argues that "[j]ust as meaning of words arises from the situational context of utterance...so also the use-value of tool-objects arises from the situation of the agent in a context of practical action” (Ingold, 1993b, p. 440). ‘Context’ is not only a matter of what an individual is doing, there is also a social aspect – the toolness of an object can be a social ‘agreement’ in that tools sometimes only make sense to and are understood by those who use them (cf. Levine & Moreland, 1991). Ingold (2000) further notes that a tool is not “a mere mechanical adjunct to the body, serving to deliver a set of commands issued to it by the mind” (p. 319). Instead it can be said, even though some find it controversial (as seen in Section 2.3), that tools extend the body, and the whole person (Ingold, 2000; Preston, 1998; Smitsman, 1997). The notion of tools as an extension of the body is also present in ecological psychology, according to which an organism and the environment form a unified system – a system that temporarily can include external elements, such as tools (further discussed in Section 3.1.3)

Another way of viewing tool use is discussed by Wynn (1993), who suggests that it should be thought of as a system in three layers. By separating tool behaviour into its layered components, we may add to the knowledge of how tools have evolved. The layers of tool use that Wynn has in mind are a

- biomechanical layer,
- a layer for the construction of action sequences, and
- a problem solving layer.

The biomechanical layer consists of constraints that are imposed by the tool-user’s anatomy and physiology. What we can and cannot do is limited to a range of possible movements. Similarly, Sheets-Johnstone (1999) points out that it is important not to disregard the role of the physical body, which has often been the case. The body’s characteristics do not emerge out of ‘nothing’, they are a further development of physical characteristics of earlier generations, and considering tools, “one designs tools congenial to the body one is, not to the body one is not; equally, one designs them congenial to the use they will be put and can be put given one’s situation” (p. 33).

The layer for the construction of action sequences concerns skill acquisition. The skills of tool use and tool making are often acquired through apprenticeship, which is largely a non-linguistic process where the novice observes a more skilled performer (cf. Section 2.2.1; see also Keller & Keller, 1996). The more experienced person’s skills consist, to a large extent, of implicit knowledge, and therefore the novice does not learn by internalising a
body of explicit knowledge. Rather, tool use may be described as learning in a relatively ‘primitive’ manner (Gauvain, 2001; Wynn, 1993), where the novice observes and memorises series of tasks. Initially he may not know how actions are related to one another, but through memorisation he learns to chain actions into longer and longer action sequences. The learned tool sequences are individualised since everyone constructs his own sequence of motor actions by repetition and rote memorisation (which applies to both adults and children).

The problem solving layer concerns the ability of adjusting one’s own behaviour to the task at hand. In Wynn’s view, problem solving may be thought of as constellations of knowledge, which include all the appropriate elements to a task, for instance, the rote motor sequences of the second layer above. As constellations are repeated over and over again, they become replaced by ‘unconscious recipes’, and it becomes difficult to describe tasks in detail (Wynn, 1993). In other words, with increased skill, gained through repeated actions, the formulation of actions undertaken in tool use becomes ever more difficult and, what perhaps previously has been verbalisable knowledge, transforms into tacit knowledge. Similarly, Polanyi (1964; 1969) as well as Dreyfus and Dreyfus (1982), for instance, describe tacit knowledge or skills as emerging through repeated practice as the novice becomes more experienced in performing a task. Alternatively, a skilled person’s knowledge could be described as being ‘densely packed’, and that it is the unpacking of the knowledge that poses a challenge (Baber, 2003). Wynn’s three layer system of tool use thus weaves together bodily aspects, skill acquisition or learning as apprenticeship, and adjustment of behaviour to the task at hand.

A question ensuing from ‘tools’ and ‘tool use’ is how to individuate the terms individualistically, i.e., from the perspective of the individual. As discussed by Preston (1998), questions that need to be addressed are, e.g., what objects should be counted as tools, and what behaviours should be counted as tool use? Suggested answers to these questions come primarily from ethology and anthropology, but according to Preston, the standard ethological definition of tool use (as formulated by Beck, see below), often applied to human behaviour, is not viable. In Animal Tool Behavior, Beck (1980) argued that “the simplicity of previous definitions...makes them imprecise and arbitrary...[and] not very useful in the reliable categorization of tool use and are therefore little better than intuitive notions”. Hence, he set out to “provide precise definitions of tool use and tool manufacture” (p. 1). Beck had several requirements for the definition of tool use, e.g., that a tool must not be attached to the body (which excludes hands etc.), and he specifically pointed out that a definition of tool use should not imply intention or an understanding of causal dynamics. He also emphasised that a tool use definition “should be free of any dependence on or reference to cognitive processes” (p. 8). It is ironic, then, that Beck’s non-cognitive tool use definition, as pointed out by Preston, is often applied to human tool use behaviour. Beck defined tool use as

the external employment of an unattached environmental object to alter more efficiently the form, position, or condition of another object, another organism, or
According to Preston (1998), Beck’s definition of tool use contains the following requirements:

- An object (the tool) must be used to do something, or alter some condition of the environment or the user.
- The object must be external and unattached to the user.
- The user must hold or carry the object in the process of using it.
- The user must be responsible for its effective orientation at the time of use. (p. 522)

These requirements run into some serious problems though, such as difficulties in drawing a line between body and tool, which lead to a number of questionable cases. However, Preston points out the necessity of these restrictions since without the control of a behavioural category of tool use, by definitional stipulations, “it either expands inward to include all behaviours involving body parts or internally processed objects, or it expands outward to include all behaviours involving any external objects whatsoever” (ibid., p. 523). However, albeit more elaborated and explicit in its formulation, as opposed to the ‘simplicity of previous definitions’, Beck’s own definition falls short of evading the arbitrariness of previous ones. Instead, the restrictions on what to count as tool use are arbitrary and an artificially maintained behavioural category (which Beck also admits). According to Preston, behaviours that are functionally the same become separated; a chimpanzee that opens a nut by pounding it with a stone engages in tool behaviour, while the same chimpanzee using the very same stone as an anvil, pounding the nut on the stone, does not engage in tool behaviour.

Preston argues that in definitions of behavioural categories of tool use lies the (unconscious) idea of formulating them in accordance with intuitive folk categories of tool and tool use. Accordingly, Beck’s definition is “essentially an attempt to formalize for scientific purposes a folk category of tool use which, in turn, underwrites definitions of ‘tool’ found in standard dictionaries” (p. 514) (cf. Section 2.4.1). However, while Beck’s definition certainly underwrites dictionary definitions, with its consideration of tools as handheld objects, there is one important difference; dictionary definitions of ‘tool’ refer to an object being used for some ‘purpose’ and that it is used in ‘the pursuit of something’. This in turn refers to cognitive processes and implies intention, and references to cognition is exactly what Beck wanted to avoid in his definition.

Preston further argues that in order to individuate tools and tool use, we need to know something about the history of the normal use of the tool. The Auchelean hand axe is an example of the difficulty in individuating tools and differentiating tools and non-tools without knowledge of the history of their

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normal use. No one really knows what the ‘hand axe’ was used for (see also Gibson & Ingold, 1993), and according to Preston, the axes have been ...the subject of much speculation, ranging from digging to projectile weapons...the flakes removed to produce the ‘handaxe’ are themselves potentially useful tools. Indeed, as Davidson and Noble (1993)\(^\text{17}\) report, some native inhabitants of Papua New Guinea who still make and use stone tools, use only the flakes—discarding the so-called core, the erstwhile ‘handaxe’! In other words, it is quite possible that the ‘handaxes’ lovingly collected by generations of paleoarchaeologists never had a normal use, let alone an actual use. (p. 519-520)

Subsequently, in Preston’s view, considering the temporal and geographical distribution of hand axes, which are found throughout Africa, Asia, and Europe, and cover more than a million years of the archaeological record, “it seems presumptuous to assume that they had a use” (p. 520). Rather than looking for a specific use, we need to consider a pattern of normal or customary use. The hand axe also illustrates what Davidson and Noble (1993) calls the ‘finished artefact fallacy’, that is, “the belief that the final form of flaked stone artefacts as found by archaeologists was the intended shape of a ‘tool’” (p. 365). In Preston’s view, then, tool use needs to be individuated non-individuallyistically, instead of following dictionary definitions which imply that tool use is performed by an individual. Preston’s conclusion is that tool use cannot be delimited as a distinct type of behaviour. She further adds “the folk notion of tool use which has been unreflectively adopted by philosopher and behavioural scientist alike simply does not stand up to scrutiny as an adequate category for either the scientific study or the phenomenological analysis of behaviour” (p. 527). Preston also argues that literature on tool use in non-human animals provides evidence that tool use is not a distinct type of behaviour. However, recent findings in primate tool use have not received much interest, e.g., in philosophy, which Preston claims that is a mistake. The same point applies to cognitive science as well (Tomasello, 2000) (cf. Chapter 4).

Bodily movements may be functionally similar, yet have different meanings. Therefore, Preston suggests a function-based taxonomy of behaviour as a more suitable approach for individuation of tools and tool use. In Preston’s view, Heidegger’s work (further discussed in Section 3.1.2) provides such a functional basis; tools, or equipment, used in everyday activities have a function, they are for something and humans perceive objects in terms of their functions. Hence, tools are differentiated by their differing functions. Heidegger also emphasises the customary forms of activity that structure much of everyday life, and in particular he stresses the customary uses of tools that provide a conventional structure to actions, space, and materials (Preston, 1998). Therefore, Preston argues that everyday activities have to be considered within the overall pattern of social and cultural activity. In that overall pattern normative practices become established and the individual’s behaviour must be interpreted within that pattern. This approach for defining tools and tool behaviour avoids some of the arbitrary demarcations

\(^{17}\) In Gibson and Ingold (1993).
encountered by Beck’s definition, but Preston considers it incomplete, and it needs to be revised and extended.

As seen in this section, it is difficult to understand tools and their use merely by attending to one or the other aspect. There are several interrelated factors operating in tool use: the tool itself, its use, and the situation of use (each of which is a complex matter in itself). The terms artefact, tool, and tool use have also been elusive as far as coherent or unified definitions are concerned. This is partly due to the fact that most attempts to define them and their use, have been either object-centred, i.e., an object is defined according to its function or some properties of the object itself, or human-centred, i.e., a tool is defined as a hand-held device, something attached to the body, based on cultural standards or in terms of a designer’s intended function. Other reasons are, of course, the differing perspectives and foci of researchers, and issues such as context dependency (for some further definitions and viewpoints on this issue, see, e.g., Bloom 1996; Gelman & Bloom 2000; Kemler Nelson et al. 2000; Pick 1997; Smitsman, 1997). To clarify and understand artefacts, tools, and their use, more theoretical work is needed. In the following section, I turn to a theory of tool use that integrates tools and humans, and considers tool use as a contextual activity.

2.4.3 Baber’s theory of tool use
One of the most fully formed theories of human and animal tool use is, to the best of my knowledge, Baber’s (2003) account of tool use as a complex psychomotor activity. The theory’s main focus is an ergonomical perspective on individual tool use. It integrates knowledge from ergonomics, design, and cognition, and views tool use as context dependent activity. Of course, tool use is also a central concern, for instance, in cultural-historical research, which is further discussed in Chapter 3. Baber’s theory differs in that it makes tool use the central issue, while cultural-historical perspectives instead consider tools (as one element of many) within the wider frame of human activity. To explain and understand tool use, Baber invokes different forms of engagement, which comprise aspects ranging from perception-action coupling to cognitive and cultural concepts. As such, Baber’s theory accords well with a situated cognition perspective on tool use. At closer inspection, however, the theory is perhaps not as ‘situated’ as it may seem at first glance.

The main focus of Baber’s theory is individuals and physical objects that are external to the user. Physical objects, or tools, are defined as physical implements and artefacts used to make changes to other objects in the environment. More formally, a tool is described as a physical object that is manipulated by users in such a manner as to both affect change in some aspect of the environment and also to represent an extension of the users themselves. The manipulation is directed towards a specific goal or purpose, and the associated activity requires a degree of control and coordination. (Baber, 2003, p. 8)
Physical objects support the user’s engagement with the world, both in terms of human-object interaction and physical engagement with an object. To describe tool use Baber proposes six forms of engagement:

1. **Environmental** engagement: the ability of an organism to respond to aspects of the environment. They can be innate, learned through S-R conditioning, or perception-action couplings.
2. **Morphological** engagement: the ability of an organism to grasp and wield objects. The object’s dimension relates to the organism’s morphology.
3. **Motor** engagement: the ability to manipulate objects. This reflects both bodily postures adopted during tool use and coordination of movement.
4. **Perceptual** engagement: the ability to interpret feedback from tool use, and to relate the feedback to a particular set of expectations.
5. **Cognitive** engagement: the ability to represent the function of tools and their characteristics. It is also the ability to coordinate actions through psychomotor skills and to relate tools to goals.
6. **Cultural** engagement. The ability to acquire tool using skills from others, and the way in which tool use reflects traditions of action.

These different forms of engagement have some similarity to Wynn’s three layers of tool use, discussed in the previous section. Although Wynn’s three levels are denser than Baber’s different forms of engagement, both include similar aspects. Of course, there is an important difference in Baber’s theory, which is explicitly concerned with tool use from an ergonomical, cognitive, and design perspective, while Wynn’s description instead involves understanding the evolvement of tools. Table 2 illustrates the corresponding levels of the two views.

<table>
<thead>
<tr>
<th>Three layers of tool use (Wynn, 1993)</th>
<th>Six forms of engagement (Baber, 2003)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biomechanical (anatomical and physiological constraints)</td>
<td>Morphological</td>
</tr>
<tr>
<td>Construction of action sequences (skill acquisition, apprenticeship)</td>
<td>Environmental Motor Cognitive Cultural</td>
</tr>
<tr>
<td>Problem solving (adjustment of behaviour to task at hand, rote motor sequences, tacit knowledge)</td>
<td>Perceptual Cognitive</td>
</tr>
</tbody>
</table>

According to Baber, the different forms of engagement apply to humans as well as other species. This allows Baber to avoid the quagmire of what is involved in ‘intelligent’ tool use, and which species might exhibit such behaviour (in general, the more complex tool behaviour is, the more intelligent it is deemed). Instead of relating tool use to intelligence, which
would miss the point, Baber argues that tool use “as a way of mediating one’s activity on the world will be as complex as necessary” (p. 4). The only necessary criteria, then, when considering tool use, is the form of engagement that is appropriate to the tool user. While this approach nicely circumvents the ‘intelligence problem’, it seems nevertheless to provide us with another version of those Aristotelian hierarchies that place humans above other animals; the more complex a tool behaviour is the more different forms of engagement it involves. Also, when discussing the different forms of engagement in relation to human and animal tool use, Baber’s argumentation becomes inconsistent (or perhaps inadequately explained), and in some aspects, even contradictory. It seems that the same or similar behaviours are ascribed to different abilities, depending on whether they are found in humans or other animals.

Baber discusses tool use in several different animal species, among them ant-lions and archer fish, and their use of sand and water, respectively. In terms of environmental engagement, the tool behaviour of ant-lions and archer fish is basically considered the result of S-R conditioning, and they are claimed to be engaged in proto-tool-use, rather than ‘real’ tool use. The notion of proto-tool-use is based on the fact that they use ‘elements of the environment’, or ‘substances’ not produced by the animal, but instead taken and reused. Ant-lions, for instance, excavate funnel-shaped pitfalls, in which they wait for prey to fall in, where upon they seize the prey and consume it. If the prey tries to escape, the ant-lion showers it with sand to prevent it from getting away. The sand is thrown by tossing the head and mandibles (Beck, 1980; Griffin, 1992). In Baber’s account, ant-lions are said to ‘project’ a substance (sand), when they toss their heads and ‘project’ sand at prey. A proposed explanation for this behaviour is that rather than being engaged in tool use, the ant-lion exhibits a preadaptive behaviour since it already possesses the propensity for head tossing and subsequently the movement of sand could be seen as an ‘incidental consequence of aggressive activity’. Similarly, Baber speculates whether tool use in baboons and capuchins is deliberate, that is, performed with anticipated outcomes, or just the result of ‘the destructive foraging practices of these primates’. It seems as if tool behaviour in these animals is an accidental by-product of another behaviour. While much animal tool use is described as stimuli-response behaviour (chimpanzees being the exception), human tool use involves all the different kinds of engagement noted above. Central to human tool use is cognitive (and cultural) engagement, or more specifically people’s interpretation of a tool’s function, and the way the interpretation is matched to inner expectations and schema. Subsequently, in Baber’s view, people can elicit a hammering function from a shoe, a rock, or a piece of wood, and there is ‘a strong cognitive component’ that handles such different representations. Obviously, environmental elements, or ‘substances’ (rock, piece of wood, etc.) can be tools, even though they are not produced, but instead taken and reused. In the case of ant lions, however, the use of sand is reusing environmental elements, which instead qualifies as proto-tool-use. However, according to Baber’s definition of a tool in the beginning of this section, there is no mention that a tool has to be produced. The point here is
not to argue that human tool use is the same as that of ant-lions, but that an inconsistent use of terms confuses rather than explains matters. The use of ‘non-produced, reused environmental elements’ are considered proto-tool-use in one case and tool use in another depending (seemingly) on the species in question.

The different schema that Baber considers, in relation to tool use, are motor schema and cognitive schema, which are related to the different forms of engagement. With regard to motor schema, it is suggested that people have schemas for defining

- appropriate grasps for manipulable objects
- appropriate coordination of actions, and
- the appropriate sequencing of actions

For cognitive schema, the proposal is that people hold schema that

- relate the appearance of objects in the world to specific goals
- relate the function of tools to previous experiences of similar tools, and
- that are shaped by enculturation and experiences of the tool-set specific to the country in which we live. (pp. 147-148)

Closely related to cognitive schema, and cognitive engagement, is the ability to ascribe some ‘meaning’ to an object. According to Baber humans have this ability, that is, they can ‘see’ some possible future use for an object. This means they form a representation of the object’s functions, which coincides with ‘cognitive engagement’ (in the list of different kinds of engagement). Chimpanzees, on the other hand, it is argued, do not have the ability to ascribe some ‘meaning’ to an object, that is, to ‘see’ some possible future use for it, since they have not been observed collecting sticks and the like for future use. Therefore, Baber assumes that chimpanzees do not need a representation for ‘useful sticks’, and that affordances are sufficient to explain the selection of sticks. Subsequently, Baber is reluctant to ascribe cognitive content to chimpanzees’ tool use and instead considers it to be environmental engagement, that is, behaviour based on perception-action coupling and ‘seeing’ the twig’s affordance. Human tool use, on the other hand, is not only a matter of seeing affordances, but also has a close relation to representations, interpretation, and expected outcomes. However, according to Baber’s tool definition, chimpanzees fishing for termites are in fact using tools, but on the basis of this ‘future use’ criterion, their tool use is not a cognitive engagement. By and large, then, animal mental or cognitive abilities are disposed of, and the ability to ‘ascribe meaning’ becomes the divider between tool use as a (human) cognitive effort and (animal)

18 The examples given by Baber are chimpanzees, who do not collect sticks for future ant dipping, and people picking up stones or driftwood on a beach, assigning them with the meanings ‘pretty’ and ‘this would make a good flagpole for my sandcastle’. However, while the former clearly is a case of tool use, the second case is less clearly so.

19 Affordances refer, in a general sense, to the action possibilities ‘offered’ by an object. The affordance concept is further discussed in Sections 2.5 and 3.1.
perception based behaviour. Baber points out that it is not clear how to distinguish between behaviours that are in response to affordances, and ones that require some kind of interpretation (i.e., the use of representations). These two views are generally contrasted, which, according to Baber, makes a ‘tortuous’ distinction and he argues that “it is equally likely for the same act of perception to exhibit features of direct and indirect perception” (p. 59, emphasis added). The crux of the matter here is how these two fundamentally different opinions could be combined. After all, the affordance concept explains perception as a direct process with no intermediary links, such as representations (further discussed in Section 3.1.3 on affordances), while indirect perception instead involves ‘some kind of interpretation’. This matter remains unexplained, other than in terms of ‘the same act of perception’ resulting in direct or indirect perception.

However, Baber does not completely deny the possibility of chimpanzees having representations. Instead he proposes that chimpanzees ‘might be using some type of representation’ due to the fact that they make fundamental mistakes. This suggests, we are told, that they have representations, but they are incomplete and not always appropriately generalised. Nevertheless, chimpanzees do not collect objects for future use. This ‘future use’ criterion is, however, problematic. It is not included in either Baber’s tool definition or the different forms of engagement, but it does provide an additional measuring point, based on human tool behaviour. However, to consider human tool use as the yard stick for other species’ tool use misses the point that each animal’s tool use is ‘as complex as necessary’. Furthermore, even though there is an effort to avoid the ‘intelligence issue’, this criterion is added to the others, which are then applied to animal behaviour. In other words, tool use is viewed from a human perspective, and implicitly the different kinds of engagement provide a hierarchical ordering with human tool use on the highest level, followed by less complex tool use in animals, down to proto-tool-use. Furthermore, considering the provided definition of tool use, and the different forms of engagement, it could be argued that the ‘future use’ aspect of tool use is a retrospective ad hoc construction for what is distinctly human tool use. It is questionable, however, just how useful a ‘future use’ criterion really is. As discussed in more detail in Section 4.1, there are cases of tool behaviour among, e.g., chimpanzees and orangutans that clearly indicate that some tools are prepared and collected for future use. Furthermore, regarding the issue of ascribing some meaning to an object, there are alternative views, such as von Uexküll’s functional tone concept, discussed in the next chapter (Section 3.1.1).

As already mentioned, a crucial aspect of this tool use theory is the focus on physical objects that are external to the user, by which psychological tools are (deliberately) excluded. With reference to Vygotsky, Baber notes that humans have the ability to ‘internalise tools’, that is, develop the ability to use psychological tools. The problem with ‘internalising’, we are told, is that the idea of amplification becomes inappropriate (amplification is further discussed in Section 2.5). Tools amplify human physical abilities, or
increases the power a user can exercise (a hammer, e.g., amplifies the ability to hit something), but when people internalise tools, they represent different aspects of the world in new ways, and then manipulate the internal representations. Therefore, internalisation takes the focus away from physical tools.

Baber notes, what he terms, four characteristics by which means of augmentation can influence performance:

1. Tools and artefacts: the technologies that we use to work on the world which supplement, complement or extend our physical and/or cognitive abilities.
2. Praxis: the accumulation and exploitation of skills related to purposeful behaviour in both work and everyday activity.
3. Language: the manipulation and communication of concepts.
4. Adaptation: the manner in which people could (or should) adapt their physical and cognitive activity to accommodate the demands of technology.

These characteristics are based on four classes of augmentation means formulated by Engelbart (1963). However, Baber’s description and use of them differ somewhat from Engelbart’s (1963) original description. For instance, adaptation (in the above list), seems to require that people conform to technological demands. Engelbart instead considers the augmentation means of training (adaptation in the above list) as the conditioning needed by people to bring their skills in using artefacts, language, and methodology (i.e., augmentation means 1, 2 and 3) to the point where they are operationally effective. Engelbart further describes use of language as the way in which the individual classifies the picture of his world into the concepts that his mind uses to model that world, and the symbols that he attaches to those concepts and uses in consciously manipulating the concepts (“thinking”). (p. 4)

In this description language resembles a psychological tool that augments or amplifies people’s thinking. Baber, on the other hand, seems to restrict language to communication of tool using skills and, as such, an ability that underlies the acquisition and sharing of skills related to tool use. Baber also sees language as related to tools in the sense that tools are ‘information bearers’, that is, a tool’s design represents how a task should be performed. These restrictions allow Baber to omit psychological tools, and to restrict amplification to physical tools. It is noteworthy that Baber excludes psychological tools, which he considers ‘manipulation of internal representations’, not as tool use. In general, however, it is considered that there are physical as well as psychological tools, and language itself (spoken or internal as concepts, heuristics, etc.) is often seen as a powerful psychological tool – it is not just, as Baber would have it, a means for communicating about tool use. The exclusion of psychological tools leaves open a route to explaining (human) tool use, and finally Baber resorts to internal representations for such an explanation. He maintains that tool use is schema-driven, and successful tool use hinges on matching a tool’s
function and the user’s inner motor and cognitive schemas. Had psychological tools been included in the theory, the concept of tool use would have been explained through the very same concept. By considering the use of concepts, etc., as manipulation of representations instead of tool use, it becomes possible to explain tool use on the basis of representations. Representations as such is not a problem here though – what is problematic is the heavy reliance on matching internal representations and (a designer’s) intended function for a tool, which leaves little room for tool use as a context dependent activity, which is a basic claim of this theory.

With regard to the notion of tools being ‘information bearers’, i.e., that their design represents their functions and how a task should be performed, Baber emphasises that ‘seeing’ a tool’s function is also in relation to the context of its use. However, when using a tool, the user becomes involved in different kinds of engagement, and the notion of engagement is strongly tied to the idea that tool use is a matter of people matching their schemas (internal representations) with the designed function of tools. This argument suggests an adoption of a design stance (Dennett, 1987), and that the intended function of an object can be conveyed through its designed properties, which is indeed what Baber argues for. According to the design stance, however, an object’s essence lies in its surface properties, not in the context of its use. Thus, even as Baber argues that a tool’s interpreted function depends, not only on appearance, but also on the context of its use, it is not clarified how these views come together. The issue here is similar to what Suchman (1987; cf. Section 2.2.1) points out when she claims that knowing how to handle unfamiliar equipment does not come from self-contained rules and procedures, but instead depends on the situational specifics. It seems the problem here is also similar to that in Fitzgerald and Goldstein’s (1999) ‘honesty of affordances’ (further discussed in Section 2.4), which implies that design is a matter of adding the right affordances to an object. On the other hand, Baber recognises that children’s play is important for the development of object manipulation, and learning about object properties and what can be done with them. Similarly, Lockman (2000) argues that “the origins of tool use in humans can be found during much of the first year of life, in the perception-action routines that infants repeatedly display as they explore their environments” (p. 137). Baber’s recognition of the importance of children’s play, however, leads to another unexplained integration of opposing views. Generally, a perception-action perspective on cognition does not easily comply with an information processing perspective, as Baber seems to (implicitly) assume. Yet, an important part of the theory is the linking of schema and the different kinds of engagement, among them perception-action coupling.

In sum, a major drawback in Baber’s theory of tool use, at least from a situated cognition perspective, is the heavy reliance on internal representations\(^{20}\), and the matching between those representations and a

\(^{20}\) Baber does not discuss the nature of representations, but his writing strongly indicates a view following mainstream cognitive science, that is, cognition as manipulation of internal symbolic representations.
tool’s designed appearances, which misses the point of accounting for tool use as a contextual, or situated activity. The theory is also tool-centric and lone-body biased (Morris, 2005), thereby excluding, for instance, the social dimension of tool use. Despite the problematic issues discussed here, Baber’s theory does provide an important account of tool use through its consideration of response to environmental aspects, motor skills, perception, cultural aspects, etc., which significantly extends beyond common views and descriptions of tool use. We will return to this theory in Section 4.1 and Chapter 5.

2.5 Artefacts and cognition

This section addresses the use of artefacts and environment adaptation from a cognitive perspective. First, we will take a closer look at cognitive artefacts and the use of affordances in the context of human-artefact interaction. We will subsequently examine two lines of work, by Kirsh and Dix et al., in which some concepts concerning artefacts and cognition are found.

What is particularly special about cognitive artefacts is the way they alter human cognition. As Wartofsky (1979) points out,

[b]y contrast with nonhuman animals, human beings create the means of their own cognition. That is to say, we create cognitive artifacts which not only go beyond the biologically evolved and genetically inherited modes of perceptual and cognitive activity, but which radically alter the very nature of learning and which demarcate human knowledge from animal intelligence. (p.xv)

The importance of cognitive artefacts and their role in human cognition was perhaps most popularised with Norman’s *Psychology of everyday things*, with concepts like affordances\(^{21}\) and misperceived affordances, and the discussion of how artefacts can aid our cognitions. According to Norman (1991), most previous research on cognition has focused on cognitive processes unaided by external devices. However, Norman argues that cognition is a **distributed** phenomenon, and the real powers of human intelligence come from the ability to devise external elements that help transcend cognitive limitations. This reminds us of Hutchins’ DC, discussed in Section 2.2.2, which emphasises the interactions between internal and external representations. Nevertheless, while DC is concerned with a system-level view, the distributed view discussed here is limited to the level of individual cognition. In Norman’s (1991) opinion, an external element, or cognitive artefact, is an “artificial device designed to maintain, display, or operate upon information in order to serve a representational function”\(^{22}\) (p. 25). In general terms, cognitive artefacts are tools of thought that complement our abilities and strengthen our mental powers. Thus the

\(^{21}\) The affordance concept appears in this section as it is usually used in, e.g., cognitive science and human-computer interaction. The origins of the concept are described in more detail in Section 3.1.3.

\(^{22}\) A problem, obviously, when defining cognitive artefacts as ‘designed artificial devices’ is the exclusion of non-designed objects. Naturally occurring things, like pebbles, can be used as a representational device for, say, remembering numbers and sums in an arithmetic task.
general claim is that such tools affect human cognitive performance as they extend and enhance cognitive capacities, or make us ‘smarter’ (Norman, 1991; 1993). The enhancement of cognition through the use of artefacts can be viewed from two different perspectives, as proposed by Norman (1993): the personal point of view, and the system point of view. From the personal point of view, cognitive artefacts are related to the individual’s cognitive capacities; the artefacts enhance cognitive abilities and allow humans to transcend cognitive limitations. A cognitive artefact transforms the nature of a task, which allows the individual to make use of other or less demanding processes. The use of a to-do-list, for instance, changes the task of remembering (single items) into the task of using the list itself. From the system point of view it is the performance of a system that is enhanced, that is, the person and artefacts taken together, since the combination of the two is more powerful than either artefacts or person alone.

Enhancement of cognition is also sometimes described as amplification of cognitive abilities. That, however, is a mistaken perspective, a misunderstanding (Cole & Griffin, 1980; Hutchins, 1995a). Even if an artefact may appear to amplify cognition, in reality no such amplification takes place. Instead, different artefacts create different kinds of representations, or representational problems, which require the use of different cognitive processes or abilities. Therefore, what takes place is a coordination of different cognitive processes, which can be aided by using appropriate artefacts/representations, but no cognitive ability or process is amplified. The interaction between internal and external representations, and the way different kinds of representations affect performance of a task, have also become the focus in what is termed an external cognition view (e.g., Cox, 1999; Day, 1988; Scaife & Rogers, 1996; Reisberg, 1987; Zhang, 1997; Zhang & Norman, 1994).

Cognitive artefacts and tools have also been discussed in terms of cognitive technology, which is, according to Pea (1987, in Ruthven & Chaplin, 1997, p. 93), “provided by any medium that helps transcend the limitations of the mind, such as memory, in activities of thinking, learning and problem solving”. Similarly, Clark (2001) refers to cognitive technology or ‘wideware’ when discussing external and (or) artificial cognitive aids. In Jonasen (2003) we find a combination of terms, that is, cognitive tools in the form of representations, and cognitive technology. Jonasen describes cognitive tools as knowledge representation tools, which are “any technologies that engage and facilitate specific cognitive activities. They amplify the learner’s thinking” (p. 372). Examples include expert systems, system modelling, and semantic networks. Jones and Nemeth (2005) distinguish between two types of artefacts; exogenous and endogenous artefacts. Exogenous artefacts are developed external to a workplace but installed for use there, while endogenous cognitive artefacts, on the other hand, are created and implemented by the users themselves to facilitate their work. In other words, these are cognitive artefacts. A difference in Jones and Nemeth’s (2005) use of these terms, in contrast to the general individualistic view on ‘cognitive
artefacts’, is a concern for endogenous cognitive artefacts as support for collective, distributed cognition.

A concept closely related to cognitive artefacts is cognitive congeniality, or the cognitive hospitality of some state (Kirsh, 1995b; 1996). Discussing different ways of improving performance in a task environment, Kirsh argues that the best way to solve a cognitive problem is sometimes to adapt the world instead of oneself. Similarly, Pea (1993, p. 48) points out that “the environments in which humans live are thick with invented artifacts that are in constant use for structuring activity, for saving mental work, or for avoiding error, and they are adapted creatively almost without notice”. Examples in this case include labels, everyday notes, and the use of space to organise piles of material on the desk. Kirsh (1996) distinguishes two families of strategies for active restructuring. The first one is to deform the topology of the state space of a task: one of the most powerful ways of achieving a change is by use of tools, i.e., to introduce a new tool, or to put an existing tool to a new use. The second strategy is to increase the cognitive congeniality (or cognitive hospitability) of existing state spaces (see also de Léon, 2003). This can be achieved with the use of complementary strategies. Such a strategy is a sequence of physical and mental actions that lead to the solving of a problem in a way that is more efficient than with the use of either physical and mental actions on their own (Kirsh, 1996). External elements that reduce the cognitive load could basically be anything that ‘encodes the state of a process’ or that ‘simplifies perception’, such as, fingers or hands, pen and paper, measuring devices, or other ‘entities’ in our immediate environment. Hands, for instance, may be used as a complementary strategy when counting coins (Kirsh, 1995a). By pointing, a person can keep track of the coins already counted, thereby off-loading his cognitive processes, and performing the task in a more efficient way. These strategies, or actions, do not primarily serve to facilitate the accomplishment of a task in terms of reaching a goal. Rather, they are undertaken because they affect the way a task is perceived and understood, and because they create cognitive affordances (Kirsh, 1996).

In order to improve performance, people also make intelligent use of space (Kirsh, 1995b). The use of space refers to different ways of encoding information in the environment, and to make reading the information less complex. Kirsh discussion relies heavily on experts and their use of space, and he argues that the effectiveness of encoding information in environmental arrangements depends on the agent’s memory, categories, and skills. Relying on the literature of expertise, Kirsh argues that expertise is characterised by compiled knowledge which makes it possible to cope, generally, without much on-line planning. A key element is ‘expert perception’, that is, to have the right perceptual categories and ‘knowing how to keep an eye on salient properties’. Skills are described as responsiveness that is automatic and unreflective, where actions are intentional but do not result from occurrent deliberation. Experts also structure their environment through informational and physical ‘jigging’. Informational jigging is the arrangement of items in order to cue the agent’s own or others’ cognitive
processes, and physical jigging is the arrangement of items in order to physically constrain actions. Such rearrangements make objects mentally and physically convenient, and they lessen cognitive demands: less visual search, enhanced noticeability, identification and memory, and simplified representation of the task. Some main points on how space is used (in informational restructuring), concern the use of space to simplify choice and perception. One way to simplify choice of an action is, e.g., by hiding or highlighting affordances. According to Kirsh (1995b),

To see an action as available for choice is to notice that it is afforded by the current situation. An affordance of a situation, crudely stated, is a way that a situation lends itself to being used...we can change the affordances of an object merely by altering its context...An affordance, as we shall use the term then, is a dispositional property of a situation defined by a set of objects organized in a set arrangement, relativized to the action repertoire of a given agent. Agents perceive an affordance, when they register that one of their possible actions is feasible in a situation. (p. 43)

Consequently, the way objects are arranged can simplify choice through the affordances ‘on display’ in a current situation. The spatial arrangement of objects can also simplify perception. For instance, objects can be clustered into categories in which they share some similarity, such as colour. A benefit of clustering is that a group of objects is harder to lose than separate smaller objects.

The use of space has also been applied to social activities of several individuals, in contrast to Kirsh’s focus on the way use of space supports individual cognition (Perry et al., 2003; Spinelli et al., 2005). According to Perry et al. (2003) several aspects apply equally well to socially distributed cognition. For instance, use of space orients people to a common perspective (in this case, a group of problem solvers). Through the spatial arrangement of artefacts, available to all people within line of sight, certain issues can be represented and explicated, which provide visibility to all. Visibility of artefacts also provides visibility of other people’s perspectives, e.g., others’ visible orientation to the artefacts cues people to interpret the division of labour within the distributed system. Furthermore, the arrangement of artefacts provides an externalised collective memory that sustains over time. Another aspect that applies in a social context, in the work of Perry et al. (2003), is that space can be used to structure social organisation. Spatial arrangements help the organisation of parallel collaborative work processes - manipulating the access to artefacts and people within a space, for instance, can structure the cognitive system in a way that is more flexible and efficient than negotiated agreements. Space also structures social organisation in the sense that it allows team members to organise their activities – space forms a supporting structure for the team’s task, which Spinelli et al. (2005) refer to as cognitive scaffolding.

Referring to the affordance concept again, a further elaboration thereof (based on Gibson’s use of the term, cf. Section 3.1.3) is found in Gaver’s (1991) sequential and nested affordances. The basic idea underlying these concepts is an explicit inclusion of exploration. As noted by Gaver, passive
observation alone does not reveal all possible operations of an object, instead they are revealed over time. A door handle, for instance, may afford grasping, but the affordances of turning it or using the handle to open the door are not indicated. Instead, it is only after the handle has been grasped and exploratively pushed downwards that the affordance or turning it is revealed (through tactile information). Once the handle is fully pressed down, it is natural to pull (or push) it, and the result of pulling it reveals whether or not the door affords opening. Sequential affordances, then, refer to “situations in which acting on a perceptible affordance leads to information indicating new affordances” (p. 4). The second concept, nested affordances, refers to affordances that are grouped in space (the idea of nested affordances is implicit in Gibson’s work, even though he did not use that specific term; McGrenere & Ho, 2000). While a part of an object may afford some kind of handling, separate parts in themselves do not reveal the possibilities of the whole object as such. In the case of a door, as Gaver (1991) points out, the affordance of pulling the door handle is nested within an affordance of opening the door.

Another affordance-related term that has appeared more recently is honesty of affordance (Fitzgerald & Goldstein, 1999). Honesty of affordance means that ‘a tool tells the truth, the whole truth, and nothing but the truth about the capabilities it has’. With reference to Gibson, Fitzgerald and Goldstein argue that the use of a natural object or artefact is determined by its properties. However, they also point out that a mapping between actual and perceived affordances is not enough. Instead, they emphasise the role of the designer who chooses which affordances a tool conveys. According to Fitzgerald and Goldstein (1999), communication is a planned activity and they argue for cognitive tools which communicate more humanely via their affordances. Here, affordances are seen as a means of communication between designer and user. The underlying idea is that the possible uses of a designed tool can be intentionally communicated through its affordances. Therefore, Fitzgerald and Goldstein argue that it is important to understand what tools can communicate, and they have formulated a taxonomy of tool communication, which includes the communicative aspect of affordances (e.g., how to communicate functionality). It is also proposed that the taxonomy can serve as a checklist for ‘truth’ analysis; each identified affordance can be described in terms of honesty, which then can be checked against the taxonomy. While this general idea is straightforward (‘design things so as people can see what they are for’), the approach is somewhat problematic. The notion of communicating through affordances implies that perceiving the right affordances (the designer’s intention) is just a matter of adding the right ones. Furthermore, this implies that there are, in fact, objective features that would be perceived the same way by all users (further discussed in Chapter 3). This approach is in line with Shannon & Weaver’s (1949) communication theory, according to which communication is a matter of encoding and decoding of symbols, and where a one-to-one mapping between sender and receiver is ensured by a reduction of noise. Furthermore, this approach is individual-centred and decontextualised, ignoring the situation of use, which affects the perceived possibilities of an
 artefact’s use (cf. Section 3.1). As pointed out by Mitcham (1994), different kinds of artefacts or tools are not always easily distinguished since

whether an object is one or the other appears to be highly context dependent and not always clearly discernible in the tool itself. If the difference is only one of context, can it be claimed as distinctive of the object? For example, numbers can sometimes be used for doing mathematics, sometimes for making money or even buildings. (p. 163, emphasis added)

Since Norman’s (1988) introduction of affordances (and misperceived affordances) in human-computer interaction in the 1980s, the concept has come to play a significant role in HCI, and in recent discussions of situated and embodied cognition (e.g., Clancey, 1997; Clark, 1997, 2003; Varela et al., 1991) as well as artificial intelligence robotics (e.g., Duchon et al., 1998; Effken & Shaw, 1992; Murphy, 1999; Prem, 1997; Stoytchev, to appear). However, along with the popular use of the affordance concept, its use has become confused and lost its original meaning altogether (Torenvliet, 2003). Part of the problem is the confusion between actual and perceived affordances. Recently, this problem has become an issue of discussion and clarification (e.g., Norman, 1999; Hartson, 2003; see also McGrenere & Ho, 2000, for a survey on different uses of the concept of affordances).

In the following two sections we will take a closer look at a few specifically artefact related concepts, which address cognition and artefacts in work contexts.
2.5.1 Triggers and placeholders

In the area of human-computer interaction, Dix et al. (1998a; 1998b; 2004) have taken an interest in artefacts within the wider context of their use, and the ways environmental resources contribute to work activities. In this line of work Dix et al. (2004) propose trigger analysis as a way to analyse work activities, and to investigate why things happen when they happen. Trigger analysis can provide a means for analysing the ways external resources initiate activities and function as reminders of where in a work process people are, as well as ensuring that tasks are carried out in full. This kind of analysis also reveals whether a certain task is robust to interruptions and delays, and identifies failing triggers that may cause a breakdown in a work task. The method contains two concepts that are of interest for present purposes; triggers and placeholders. A trigger is described as something that prompts an activity, something that tells a person that he or she needs to do something. Triggers identified by Dix et al. (1998a; 2004) include:

- **Immediate**: takes place when an activity begins immediately after a previous task is completed (e.g., open post as soon as it has been brought to the desk).
- **Temporal**: actions that happen at regular intervals or after a particular delay (e.g., check diary first thing every morning, send a reminder letter two weeks after the original letter was sent, regular routines).
- **Sporadic**: when someone remembers that something must be done (e.g., remembers to write something in a diary after having been interrupted)
- **External event**: some external event occurs (e.g., phone call, face-to-face request, signal/reminder from automatic calendar).
- **Environmental cue**: something in the environment that reminds us that something needs to be done. The cues are coded explicitly (e.g., to-do-list, entry in calendar) or implicitly (e.g., half-written letter).

All these triggers, except one, are directly related to the individual’s use of artefacts, and the triggering functions of artefacts. The trigger ‘external event’, however, demonstrates that not all activities are triggered by material resources, but also contain a social element. For instance, we ask other people questions, remind others and sometimes we specifically ask them to remind us of certain dates or meetings, etc.

Besides knowing that something needs to be done, people also need to know what must be done. The placeholder concept refers to things that tell a person what he or she needs to do. Placeholders help people keep track of where in the process they are, reminding them of what to do next, which ensures that tasks will be carried out. Placeholders are stored in different ways (Dix et al., 2004):

- In people’s heads: when they remember what to do next.
- Explicitly in the environment: to-do-lists, planning charts, notes.

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23 This section appeared in similar form in Susi (2005c).
Implicitly in the environment: whether the in-tray is empty yet.

Like the triggers described above, placeholders are also individual-oriented. Some triggers and placeholders may also seem very similar to one another, but in a few cases one and the same artefact can be both a trigger and a placeholder, the difference being their function. A to-do list, for instance, may trigger an activity written on the list, and, at the same time, it may be a placeholder indicating what needs to be done next. Likewise, being reminded by others, can be both a trigger and a placeholder. Some triggers and placeholders are also endogenous cognitive artefacts (cf. previous section), that is, cognitive tools created by an individual in order to facilitate his/her own work.

A primary focus in this line of work is work processes, and central issues, as seen above, are why things happen when they happen, and how people know what to do next. A question that remains unanswered, however, which they themselves point out, is what makes someone notice a cue in the first place (Dix et al., 1998a). Some possible answers can be found in Kirsh’s work regarding the use of environmental resources and active restructuring of the environment, which is discussed in the following section.

2.5.2 Entry points

Kirsh argues that concepts like reminders, placeholders, and triggers are “surface structures” that may help understand work contexts, but they do not help us gain more insight into their deep structure. Instead, he argues, environmental elements need to be described in more abstract terms (Kirsh, 1996; 2001). Kirsh describes some of the ways people actively use environmental resources to structure their work, e.g., in offices. Some central concepts include activity landscapes, coordinating mechanisms, and entry points. In short, activity landscapes are people’s interactively constructed workspaces, whereas coordinative mechanisms refer to the use of environmental resources that help people achieve their goals. In the present context, however, it is the entry point concept that is of most interest. In Kirsh’s use of the term, an entry point refers to “a structure or cue that represents an invitation to enter an information space or office task” (2001, p. 305). As such, entry points are similar to affordances, in that they invite people to do something, and the use of entry points is a way of achieving cognitive affordances. Entry points in an office are, e.g., folders, to-do-lists, and day planners. The entry points that office occupants create have different properties, or characteristics that affect the way people react to them, properties that vary along a number of key dimensions:

- Intrusiveness: how much attention the entry point attracts.
- Richness in metadata: how much the entry point reveals about the underlying information.

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24 This section appeared in a similar form in Susi (2005c), and parts of it appeared in Susi and Ziemke (2005).
- Visibility: the higher the visibility, the greater the chance the entry point will be used.
- Freshness: recently touched entry points are more likely to be used in current activity.
- Importance: refers to how pressing the activity that is associated with the entry point is.
- Relevance: the usefulness of the entry point in current activity.

According to Kirsh (2001), most of these entry points are created by the workplace occupants themselves and the number of entry points created varies from one office occupant to another. Entry point collections are also personal and subjective as preferences for the number and type of entry points differ. Such collections can also, as discussed previously, be described as endogenous cognitive artefacts, created in order to make the work easier (Jones & Nemeth, 2005). Different kinds of entry point collections are well illustrated by the workplaces of so-called “neats” and “scruffies” (Kirsh, 2001). In the following images we see the (extreme) opposites of workplace structures, created by the office occupants themselves. Figure 1 illustrates the clean desk of a so-called “neat” with only a few entry points (the desk belongs to one of my colleagues at the University of Skövde). The tidy desks of “neats” have only a few items on them, which provide a ‘clean’ structure with a controlled amount of entry points. In the picture below we see, for instance, a paper on each side of the key-board (with a post-it note on the left one), and folders in different colours to the left on the desk (the office occupant is at lunch, and has written ‘lunch’ on the whiteboard).

![Figure 1. The workplace of a "neat", with few entry points.](image-url)
So-called “scruffies”, on the other hand, are (or at least seem to be) less in control. Their desks are filled with all the kinds of things found in an office, and they make use of ad hoc categories to a greater extent, that is, they create categories as needed. Figure 2 shows the desk of a “scruffy” with many entry points (the desk belongs to another colleague). There are different piles of papers, documents placed between the key-board and computer screen, others attached to the lamp on the desk (to the right of the computer screen), post-it notes with things to do, etc.

These office occupants have created their own structures, and whether there is a high or low degree of structure (from an external observer’s perspective), each provides external scaffolding for their own work tasks. Kirsh (ibid.) explains that people create collections of entry points and when the office occupant returns, he/she scans these entry points and picks up as much metadata and ‘information scent’ as necessary to gain a high level picture of what is on the agenda, thereby developing a rough plan for moving through his/her activity landscape.

Some of the entry point dimensions are described as objective (intrusiveness, richness in metadata, visibility, freshness), and some as subjective (importance, relevance). Considering that entry points are similar to affordances, and that an object’s affordances are found in the object itself (object X affords/invites this or that activity), the objective-subjective distinction is somewhat unclear. This is a relevant issue when considering whether the use of entry points is context dependent or not. Firstly, objective entry points may seem as context independent as they are properties found in the environment, inviting an action, and whether they are perceived or not
depends on how much attention they attract. Furthermore, subjective entry points seem to be context dependent, as they are directly related to the office occupant and his/her ongoing work tasks. However, it could be argued that, in fact, all dimensions of entry points could be considered context dependent, since an ongoing work task may affect what the office worker looks for in the first place. Kirsh seems to, more or less, equate entry points with affordances, and it is not really clear in what way Kirsh distinguishes the two, or why the term entry point is chosen for what seems to be affordances (in Gibson’s terms, cf. Section 3.1.3). As an office occupant and the office co-adapts, and she/he actively structures the environment by creating an entry point collection, it seems the entry point collection is directly related to the active agent, rather than any agent(s), as implied by “objective”. From an ecological perspective, entry points would be objective in the sense that they are found in the environment, inviting us to take action. However, considering, e.g., ‘freshness’, which is an objective dimension, it is not clear in what way it is objective. The time laps between touching an item does not seem an objective property since there is nothing in an item itself that reveals when it was last touched (unless for instance, a date has been added to a document, in which case it probably would fall into one of the other dimensions). Therefore, ‘freshness’ seems more related to a person’s characteristics (such as memory), rather than the characteristics of an item. The time of use of an object is also directly related to the person who has used the object, not to other users in general. Freshness is therefore only meaningful to that specific person (unless one deals with cooperative processes, which is not the case in Kirsh work). Considering that entry points are related to the work performed by an office occupant, all entry points could actually be seen as subjective and context dependent.

Consequently, the entry point, trigger, and placeholder concepts provide different artefact related conceptualisations. Kirsh investigates how active subjects make use of environmental structures to scaffold their daily work and to achieve various work tasks. Emphasis is on the co-adaptation of agent and environment (or office occupant and office), i.e., the individual’s cognition and his/her use of artefacts. The structure provided by entry points reduces cognitive demands and helps people to improve their performance. Dix et al.’s work, on the other hand, primarily focuses on work processes, why things happen when they happen, and how people know what to do next. The ‘why’ and ‘what’ is explained through triggers and placeholders, which include both material and non-material artefacts. While Dix et al. separate the things that trigger an activity from those that tell what needs to be done, Kirsh instead conlates both these aspects in the entry point concept.

In sum, entry points are concerned with artefacts’ characteristics and how they affect the way people react to them, which is an aspect missing in the trigger and placeholder concepts. On the other hand, the trigger and placeholder concepts contain a temporal aspect not covered by the entry point concept (the entry point ‘freshness’ is a temporal dimension, but it is not concerned with the temporal aspects of work, only the length of time.
since an item was used). Common to both lines of work is a focus on the individual's use of environmental resources, and they lack a relation to the wider context of activities, especially its social dimension. What is gratifying about these concepts though, is the way they actually complement each other and provide a two-dimensional (process and characteristic) description of some artefact related aspects of human activities. Therefore, I have combined these concepts, as seen in table 3, in which the rows include the different dimensions of entry points, and the columns include triggers and placeholders. The x:s exemplify where the concepts coincide, but the placement of an “x” depends on the activity and setting under study. Subsequently, the table would vary according to different settings. A schedule, for example, may be an important placeholder and a trigger that vary along the different dimensions (entry points) in one setting, but only play a minor role or do not exist at all, in another.

Table 3. Triggers and placeholders (columns), “knowing that” and “knowing what”, integrated with entry points (rows) which describe different properties of artefacts. Each “x” exemplifies a case where the concepts complement each other.

<table>
<thead>
<tr>
<th>Entry points</th>
<th>Triggers</th>
<th>Placeholders</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Imme-</td>
<td>Temp-</td>
</tr>
<tr>
<td>Immediate</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Temporal</td>
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Objective Intrusiveness

Metadata rich

Visibility

Freshness

Subjective Importance

Relevance

Comparing Kirsh’s and Dix et al.’s concepts with Wartofsky’s (1979) and Engeström’s (1991) classifications (Section 2.4.2), it is obvious that these do not easily conflate into one classification that covers all aspects. For instance, entry points, triggers, and placeholders could be seen as primary or ‘what’ artefacts, as they all ‘go directly into production’; they are, so to say, used as and when an activity unfolds. On the other hand, not all entry points, triggers, and placeholders are primary, or external entities. The entry point ‘richness in metadata’ for instance, could qualify as a secondary artefact since it represents underlying information. However, entry points are not about an object per se, but its properties. These various classifications and concepts have different foci and concern different levels of abstraction of human activities. Wartofsky and Engeström make classifications of the things people deal with in their daily activities: things directly used in production, general and specific types of artefacts/representations, and imaginary or visionary artefacts. These categories provide a description of what people use, how some specific artefact is related to another one, people’s future visions, etc. However, the categories do not reveal what
makes people act, or how they know what to do next, and they say nothing about what makes someone take notice of some object in the first place. These are the kinds of questions that Kirsh and Dix et al. address in their works. They focus on particular details of work processes and artefacts on a level of detail not included by Wartofsky and Engeström. These different concepts, then, can be seen as complementary, providing theoretical conceptualisations from different perspectives.

As seen in this section (2.5), common to much work on artefacts (representations, etc.) and cognition, is a focus on how artefacts affect individual cognition, with an emphasis on their augmenting role. The individualistic approach to studying cognitive artefacts has caused criticism, e.g., from a socio-cultural activity theory perspective. Kaptelinin (1996a), for instance, argues that assuming the boundaries between different components from the onset, as in Norman’s personal and system point of view, leads to conceptual confusion. For instance, there is a general claim that cognition is not confined to the ‘inside’ of individuals. At the same time there is an implicit identification of ‘individual’ with ‘internal’ (individual unaided by external means), while external or distributed cognition (in Norman’s view) is the individual aided by artefacts. According to Kaptelinin, this means everything that is not internal is not individual either. Consequently, individual cognition is what takes place inside the head, which contradicts the initial claim that individual cognition is not confined to the ‘inside’. These kinds of boundaries also maintain a dichotomy between internal and external, which, e.g., cultural-historical approaches avoid by focusing on activities and mediation rather than an individual’s cognitive processes (Kaptelinin, 1996a; Arievitch, 2003). A focus on individuals also disregards cultural aspects and the social aspect of ‘external’ cognition. As Pea (1993, p. 48) points out, the “ubiquitous mediating structures that both organize and constrain activity” include material objects as well as people in social relations. Focusing on individuals, these approaches also lack a consideration for cognitive artefacts in relation to social interactions, that is, how artefacts affect such interactions. We will return to the issue of cognitive artefacts in relation to the social aspects of external cognition in later sections.

2.6 Describing artefact, tool, and tool use

As mentioned in previous sections, the terms ‘artefact’ and ‘tool’ are not easily distinguished or defined, and there are no coherent definitions. There is also tool use to consider, and the problem of defining behaviour related to tool use. However, by now it should be clear that from a situated perspective, tool use and cognition cannot be understood by analysing either a tool in itself, or cognition separated from tool use. Generally, as seen in Section 2.3, attempted definitions of artefact and tool tend to be either agent-centred or object-centred. Agent-centred definitions focus on, e.g., a designer’s intended use of an object, a user’s pursuit of a goal, or cultural standards. Object-centred definitions, on the other hand, place focus on the object itself, for instance, its features and affordances.
In contrast to these either-or views, a situated cognition perspective (generally speaking) focuses on issues such as context of use, and the dynamic interaction between agents and their environments. Considering that objects can be put to different uses depending on the person’s needs and purposes, etc., as well as the situation at hand, it can be argued that the meaning of an object, its ‘toolness’, is not something inherent in its intended function, or in the characteristics of the object itself. Rather, the ‘toolness’ of an object lies in its utility for a user, or users, to achieve an end or a purpose within a certain context, and sometimes the ‘toolness’ of an object is socially agreed. Even as people make use of an object in order to achieve something, they are not always aware of it. For instance, the spatial arrangement of objects is one way of structuring work environments and tasks, but it is unlikely that people are always consciously aware of, or think about, the meaning of such arrangements.

This also implies that a description of tools and tool use cannot be ‘free of any dependence on or reference to cognitive processes’, as in the case with Beck’s definition of tool use (Section 2.4.2). Hence, considering terms like ‘tools’ and ‘tool use’ without reference to cognition, would only provide a partial understanding of tool use. To describe situated tool use, it is meaningless to provide a precise definition of single objects, since such a definition would only be a one-sided snap-shot description. From a situated perspective, tools and their use may be described in the following way:

A tool is any object perceived by an agent, or agents, as a tool, and which is used as a means for achieving some purpose (whether the agent is aware of it or not). As such, tools scaffold individual as well as distributed cognition, and extend the capacity of an agent, or agents, to operate within a given situation.

The term artefact has been omitted in this description. Artefacts may be considered as a general, wide category of things that includes manufactured (modified, etc.) objects in our surroundings. These are the things that are ‘there’, but are not necessarily used in order to achieve something. Tools instead incorporate a narrower category of things used for a purpose. Although this is a quite general description that might seem to include most everything, it is deliberately intended to include the individual agent as well as a group of agents. Furthermore, even though this thesis emphasises first and foremost material tools, the fact that not all tools are external material objects cannot be neglected; as previously explained hands, for instance, may be used as a tool for keeping track of a process. The following chapters also discuss psychological and social tools. In Section 6.1, I will return to this description of tool use, and integrate it with some further aspects discussed in Chapters 3 and 4.
3. Historical perspectives

The first section (3.1) of this chapter addresses some perspectives on the relation between an agent and its environment, and more specifically, how subjects perceive objects and their (possible) use. The theoretical views discussed are those of von Uexküll, Heidegger, and Gibson, with focus on some object related concepts: functional tone, equipment, and affordance. Sections 3.2-3.4 provide additional historical perspectives that consider agents in relation to their environments (although not generally described in those terms); the cultural-historical theories by Vygotsky, Leontiev, and Gal’perin, which all consider the individual within the wider context of activity, that is, in relation to the social and material environment.

3.1 The relation between agent and environment

The following sections (3.1.1-3.1.3) will discuss three different conceptions of agent-environment relationship, proposed by von Uexküll (1864-1944), Heidegger (1889-1976), and Gibson (1904-1979). Their theories are not extensively recounted in this thesis. Instead, the discussion is limited to a consideration of the concepts of functional tone (von Uexküll), equipment (Heidegger), and affordance (Gibson). Even though these concepts concern the same basic phenomenon, they differ quite substantially in some aspects and provide different perspectives on the issue. In some cases they might complement each other, and in others there are clear contradictions. Even though these concepts have developed within different disciplines (theoretical biology, philosophy, and psychology) they are used more or less interchangeably in much of the literature, and are typically conflated under the label of ‘affordance’. The focus in this section is on the way physical objects in a subject’s surroundings, and their possible uses, are perceived, the way we ‘objectify’ or ‘toolify’ some object. How we perceive some certain functionality seems to be quite interesting, at least, for human cognition. Prem (1997), for example, following Heidegger, has pointed out that usually “[t]he world presents itself in the equipmental nexus”, that is, we perceive the world and objects in it in terms of their possible uses. Whether indeed the world “presents itself” that way, or if we attribute it with that functionality is one of the issues discussed in the following sections. Even though the issue of how to view the agent-environment relationship is one of the oldest issues in philosophy and science, it has re-appeared recently in discussion of, for instance, “distributed cognition” (Hutchins, 1995a), or the “extended mind” (Clark & Chalmers, 1998; Wilson, 2004), as discussed previously (cf. Chapter 2).

3.1.1 Functional tone

The German biologist Jakob von Uexküll was strongly inspired by the Kantian insight that all knowledge is determined by the knower’s subjective ways of perceiving and conceiving. Therefore, he considered it the task of biology to expand Kant’s research by investigating the role of the body in

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25 This section appeared in a similar form in Susi and Ziemke (2005).
determining the relationship between subjects and their objects (von Uexküll, 1928; cf. Ziemke, 2001; Ziemke & Sharkey, 2001). A central point in his work is the idea that each animal ascribes meaning to the physical objects it encounters, and thereby fits the world to itself, constructing its own subjective universe, or Umwelt. The Umwelt is a closed unit consisting of the subject’s perceptual world (Merkwelt, everything that the subject perceives) and his effector world (Wirkwelt, everything it does). But how do we come to see the purpose of things, for instance, that a chair is for sitting, or that a cup is for drinking? In the closed unit of subject-object interaction, the objects acquire what von Uexküll (1982; 1992) termed functional tone. An example that illustrates this concept is von Uexküll’s description of a man who had not previously encountered a ladder. When asked to climb the ladder the man wondered how he was supposed to do that as he saw nothing but rods and holes, which were his receptor image, that is, a collection of sensory features. Once the man was shown how to climb the ladder, he perceived the “rods and holes” as a ladder. What took place was that “the receptor image of rods and holes had been supplemented by the effector image [a meaningful perception of the world in terms of action potential] of his own action; through this it had acquired a new meaning. The new meaning manifested itself as a new attribute, as a functional or effector tone” (von Uexküll, 1992; p. 358). Hence subject and object are tied to each other through several functional circles through which an object is connected to the subject (von Uexküll, 1928; 1982; 1992). Von Uexküll viewed such functional circles also as meaning circles “whose task lies in the utilization of the meaning-carriers” (1982, p. 36). Initially, an object may be neutral (as in the above case of the ladder), but

it is transformed into a meaning-carrier as soon as it enters into a relationship with a subject...Through every relationship the neutral object is transformed into a meaning-carrier, the meaning of which is imprinted upon it by a subject. (von Uexküll 1982, p. 27-28)

Von Uexküll further considered that objects are “always transformed into perceptual cues or perceptual images and invested with a functional tone. This alone makes them into real objects, although no element of the functional tone is actually present in the stimuli” (1992, p. 383). Furthermore, “everything is altered and reshaped until it becomes a useful meaning-carrier; otherwise it is totally neglected” (1982, p. 31). Once a relationship has been formed, objects may assume different qualities, as in the example of a stone lying on a road, which provides support for walking, and as such it has acquired a “path-quality”. However, if the stone is picked up and thrown at an angry barking dog, in order to chase it away, the stone is imprinted with the meaning “missile” and thereby acquires quite a different quality, namely a “throw-quality”. Despite the change in quality, the change does not depend on some properties of the object itself, since its properties have not changed. Actually, in von Uexküll’s view, there are no properties of an object that identifies what it is, since “all the properties of objects are actually nothing more than perceptual cues that are imprinted on them by the subject with which they enter into a relationship” (1982, p. 74). Instead, it is the subject’s prevailing mood that underlies the different
imprintings (von Uexküll, 1982). Von Uexküll used the findings from studies on hermit crabs as an example. To the crab an “object” such as a sea anemone changes its meaning depending on its prevailing mood, as seen when the crab is presented with a sea anemone under three different conditions: a) the actinians the crab carries on its shell, for protection, have been removed, b) the entire shell has been removed, and c) the crab had a shell and actinians, but had been left without food for some time. The studies demonstrated that the receptor image of the sea anemone assumes different “tones” in the crab’s world, depending on the subject’s changing mood. With its camouflage (the actinians on the shell) removed, the crab assumes a “defense tone”, which shows through the crab’s act of placing the anemone on its shell. In the case of removing the crab’s shell, the sea anemone instead assumes a “dwelling tone”, and the crab places the anemone on its shell. If the crab has not been fed for some time the anemone instead assumes a “feeding tone” and the crab starts eating it. Hence, as von Uexküll pointed out, “[i]f an object is used in different ways, it may possess several effector images, which then lend different tones to the same perceptual image. Thus a chair, for instance, may assume a “sitting tone”, or it may occasionally be used as a weapon since it is the subject’s mood that “determines which functional image will lend its tone to the perceptual image” (1992, p. 358).

Thus, according to von Uexküll, each subject lives in its own subjective universe, in which subject and object form a closed unit. Initially objects are neutral, but as a subject enters into a relationship with an object, the latter becomes meaningful. Subjects imprint meaning upon the objects and transform them into meaning-carriers. As an object becomes a meaning-carrier it assumes a certain functional tone. Which functional tone it assumes depends on the subject’s prevailing mood and, consequently, one and the same object may acquire different meanings.

3.1.2 Equipment
The concept of equipment was developed by the German philosopher Martin Heidegger. His work has some fundamental overlaps with that of von Uexküll, but his main concern was humans rather than animals, and he paid much attention to the individual’s social and cultural embedding. To begin with, Heidegger strongly opposes the traditional Cartesian subject/object distinction, and the idea of there being something mental (intentional, representational, etc.) constituting the relation between subject and object. In Dreyfus words, “the stand Dasein takes on itself, its existence, is not some inner thought or experience; it is the way Dasein acts...Dasein takes a stand on itself through its involvement with things and people” (1991, p. 61). Heidegger turned his attention beyond the mere subject-object relation, and sought to explain what it means for something to be, or to exist. In his view, the subject-object relationship can only be understood in terms of being-in-the-world. The basic form of being, and “[t]o exist then means, among other things, relating to oneself by being with beings” (Dreyfus 1991, p. 61). Being is divided into being-human (Dasein) (which is concerned with being, and is not to be taken as an entity), and non-human being. Non-
human being in turn, is divided into Zuhandenheit and Vorhandenheit, usually translated into “readiness-at-hand” and “presence-at-hand”. According to Dreyfus (1991), however, the meaning of these terms is better conveyed by availableness and occurrentness (further discussed below).

Non-human beings, or things (Zeug), that we encounter in our everyday activities, including tools, materials, etc., are termed equipment or useful things:

We shall call those entities which we encounter in concern ‘equipment’. In our dealings we come across equipment for writing, sewing, working, transportation, measurement. The kind of being which equipment possesses must be exhibited. (Heidegger, 1927/1962, p. 97)

We shall call the beings encountered in taking care useful things. In association we find things for writing, things for sewing, things for working, driving, measuring. We must elucidate the kind of being of useful things. (Heidegger, 1927/1996, p. 64)

A basic feature of equipment, or a useful thing, is that it is used in order to get something done. Basically, a useful thing is something-in-order-to, and in Heidegger’s view, the totality of useful things is constituted by different kinds of ‘in-order-to’, such as serviceability, helpfulness, usability, and handiness (Heidegger, 1927/1996, p. 64).

The notion of in-order-to carries with it a reference of something to something, which conveys that there is nothing such as an equipment, or a useful thing. Instead “useful things always are in terms of their belonging to other useful things” (Heidegger, 1927/1996, p. 64), and there is always a totality of things, an equipmental whole, in which a thing is what it is. In the equipmental whole, things are defined in terms of their different functions, but in order for an object to actually function, it must fit into the context of meaningful activity. This fitting (Bewandtnis) of an object into a wider context is termed involvement (Heidegger, 1927/1962), or relevance (Dreyfus, 1991; Heidegger, 1927/1996), meaning that objects have an involvement with other objects. For instance:

the thing at hand which we call a hammer has to do with hammering, the hammering has to do with fastening something, fastening something has to do with protection against bad weather. This protection ‘is’ for the sake of providing shelter for Da-sein, that is, for the sake of a possibility of its being. Which relevance things at hand have is prefigured in terms of the total relevance. (Heidegger, 1927/1996, p. 78)

Thus anything we use has multiple references to other tools and purposes, and “[t]he world presents itself in the equipmental nexus, in the reference to a previously seen whole” (Prem, 1997, p. 11). The involvement of things implies that they may be chained, as in the above quote. In addition, chained

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26 Dreyfus (1991) points out that the standard translation (by Macquarrie & Robinson, 1962) terms “to encounter” (Begegnen) as humans encountering things, but in Heidegger’s use of the term it is the other way around - things encounter us, or show up for us.
assignments conclude with equipment that performs just a function, and they also end with the specific user for whom the function is performed. Thus, any piece of equipment has a “last basic assignment” in the form of “where-of” it has been made, which can be something produced or a natural product. Hence, even raw materials may become equipment as they are brought into a context of use (Preston, 1998).

The concept of involvement reveals the close interconnection between subject and object. As explained by Dreyfus (1991), there is really no distinguishable subject and object, even though we might try to consider an “objective” and a “subjective” aspect of the referential whole, but the bottom line is that “the involvement whole and Dasein’s life are both organized by the same for-the-sake-of-whichs”:

On the one hand, Dasein needs the referential whole and the involvement whole to be itself. On the other hand, the ‘objective’ or equipment side is organized in terms of for-the-sake-of-whichs that are ways of being Dasein. The referential whole only makes sense because it all 'hangs,' so to speak, from for-the-sake-of-whichs that are Dasein’s ways of taking a stand on itself, and Dasein exists and makes sense only because it takes over the for-the-sake-of-whichs that are built into and organize the involvement whole. (Dreyfus, 1991, p. 98)

As mentioned above, things are what they are on the basis of their usefulness or functionality, which makes functionality a defining characteristic of equipment. However, even though objects generally are perceived in terms of their functions, their function is not determined by some perceived “objective” or context-free features, because (visual) perception per se is not the mode of access to study functioning (Dreyfus, 1991). Rather, equipment is what it is only when it is actually taken up and used.

The less we just stare at the thing called hammer, the more actively we use it, the more original our relation to it becomes and the more undisguisedly it is encountered as what it is, as a useful thing. The act of hammering itself discovers the specific ‘handiness’ of the hammer. We shall call the useful thing’s kind of being in which it reveals itself by itself handiness. It is only because useful things have this 'being-in-themselves,' and do not merely occur, that they are handy in the broadest sense and are at our disposal. No matter how keenly we just look at the ‘outward appearance’ of things constituted in one way or another, we cannot discover handiness. (Heidegger, 1927/1996, p. 65)

Discovering the function of an object, then, is connected to its use, and to the manipulation of it, which reveals what the object is and its possible use. This in turn might imply that functions can only be understood through actual manipulation, but in Heidegger’s view, actual use of equipment gives rise to primordial (first-hand) understanding of it. At the same time though, equipment also has public characteristics, it is what it is regardless of who the user is, it is for a general user. Knowledge of the normal functions of equipment gives us a positive (second-hand) understanding of it (Dreyfus, 1991). Thus, even though the functioning of a piece of equipment becomes available through manipulation, our understanding of equipment also depends on social norms and conventions for how things are normally used.
The point of emphasising manipulation is that “theoretical knowledge depends on practical skills”, that is, the need of an embodied subject. However, neither knowledge nor manipulation is considered more important than the other, since neither one constitutes or explains the relation between subject and object. The use of objects is also affected by how fluently their use proceeds. As long as there are no disturbances objects are available to us, and we are not aware of (or deliberately thinking about) how to use a particular object. However, when work is disturbed by something, the object becomes occurrent (Dreyfus, 1991). Disturbances include, e.g., malfunction (conspicuousness) in a piece of equipment, and total break-down when a piece of equipment is missing (obtrusiveness). The basic idea, that it is only when the use of an object is disturbed that it becomes occurrent, reminds us of Suchman’s point on *occurrentness of representations* (discussed in Section 2.1.1). As mentioned, she argued that as long as an action proceeds smoothly it is transparent. Furthermore, in actions including objects, the objects tend to be ‘transparent’, or ‘disappear’, as long as their use proceeds well. It is only when an action becomes problematic or there is a breakdown (e.g., when some equipment is unfamiliar) that a representation occurs. A difference in these views, of course, is that what ‘occurs’ in Heidegger’s case is the object itself, while in Suchman’s case it is a representation (an objectification or explication of the action).

To summarise, for Heidegger, there is an interdependent relation between subject and object, and they cannot be considered as separate entities. Subjects must be considered in their form of being-in-the-world, and objects cannot be defined according to some ‘objective’, context-free properties. Objects always have involvements with other equipment and therefore the meaning of terms such as “readiness-at-hand” or “presence-at-hand”, cannot be considered in isolation. Therefore, the way a tool, and its possible use, is perceived depends on the subject’s ongoing activity. A piece of equipment has to fit into the context of an activity, since it is only within a meaningful context an object is what it is. Heidegger also emphasised the importance of manipulation, through which we come to understand an object’s functionality. Functionality can also be understood in terms of *positive* understanding when there is no first-hand experience, that is, we generally know the customary way of how to use a thing. Heidegger further stressed that neither knowledge nor perception can explain the relationship between subject and object, instead we need to look beyond that distinction, i.e., what it means for a being to exist.

### 3.1.3 Affordance

The concept of *affordances* is found in American psychologist James J. Gibson’s *ecological psychology*. As a starting point, Gibson, like Heidegger, did not agree with the traditional psychological dichotomisation between mind and body, or ideas of some psychological process operating upon incoming bodily sensations. Instead, perception is direct with no intermediary processes. In Gibson’s view, each animal has its own niche in the environment, which is considered to consist of a set of affordances. At first, this might sound very similar to von Uexküll’s theory, but Gibson
‘locates’ his affordances in the physical environment. The affordances of the environment are what they provide or offer an animal, or more formally “the affordance of anything is a specific combination of the properties of its substance and its surfaces taken with reference to an animal” (Gibson, 1977, p. 67). Affordances are neither purely objective nor purely subjective properties, instead an affordance cuts across the subject-object distinction and points to the reciprocal relationship between the animal and its environment (Gibson, 1986). Hence, “affordances are the entry point into the mutuality between an animal and its environment” (Wagman & Carello, 2001). In Gibson’s view, what we perceive of the environment is not “space” or qualities, but surfaces and affordances. Subsequently, it is the ambient light that makes information available about reflecting surfaces, and “the affordance itself is specified in ambient light” (Gibson, 1986, p. 143). Gibson’s use of “information” is quite different from the traditional meaning of “communication through a channel” (as in the view of Shannon and Weaver, 1949). Instead, information (for vision) is “a geometric concept defined over a transforming optic array, the 360° solid angle of variations in ambient light intensity converging on a point of observation from all directions” (Mace, 1977, p. 50). Hence, information is available in the optic array, the pattern of light that reaches the observer’s eyes from reflecting surfaces in the environment.

As for qualities, Gibson argues that if we are required to, we can discriminate qualities, such as colour, texture, or shape, but what we normally pay attention to is the “unique combination of qualities that specifies what the object affords us” (1977, p. 75). A flat surface, for instance, around the height of the knees, affords sitting-on, while an elongated object of moderate size and weight affords pounding-with. Gibson (1986) made a distinction between attached and detached objects, and considered tools to make a special kind of detached objects that is graspable, portable, and can be manipulated. A tool can (temporarily) be attached to the body, and extend the capacity of perceiving and acting. As a tool is attached to the body, it is no longer a part of the environment of the user. But when not in use, the tool is simply a detached object of the environment, graspable and portable, to be sure, but nevertheless external to the observer. This capacity to attach something to the body suggests that the boundary between the animal and the environment is not fixed at the surface of the skin but can shift. More generally it suggests that the absolute duality of ‘objective’ and ‘subjective’ is false. (Gibson, 1986, p. 41)27

An object, then, is not a tool just because the object is conceived of or has been labelled as such, rather tools make a special class of objects that can be attached to the body to fulfil specific functions, are graspable, and so on. Furthermore, tools extend our capacities for perceiving and acting, that is, they extend the organism’s effectivities. Hence, “a tool is the function of an object for an agent, and to be considered a tool, the object must serve to

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27 Gibson’s claim regarding the flexible boundary has very recently been shown to be, at least partly, true in cognitive neuroscience experiments with macaque monkeys using handheld tools (Maravita & Iriki, 2004; see also e.g., Berti & Frassinetti, 2000).
extend the agent’s effectivities” (Wagman & Carello, 2001, p. 174; Smitsman, 1997). It may also be assumed that as long as the use of such bodily extensions proceeds smoothly, they ‘disappear’ or become ‘transparent’, and occur only when their use is disturbed (cf. previous section). The above quote also points to the problematic subject-object distinction, which ecological psychology avoids by turning its attention to affordances. As mentioned earlier, affordances are relative to an animal, and as Gibson emphasises, they are “a combination of physical properties of the environment that is uniquely suited to a given animal–to his nutritive system or his action system or his locomotor system”. Concerning tools, Gibson also adds that when manipulability is perceived by an observer, it is “in relation to his hands, to which the object or tool is suited” (1977, p. 79). A hammer, for instance, is (generally) perceived as well suited for pounding nails, fitting both the task and the hand. As the hammer is used, the user’s needs may change though. Instead of pounding, the reversal action of pulling out a nail may be required, in which case the user perceives other affordances. However, contrary to von Uexküll’s view of functional tone, which depends on the subject’s prevailing mode,

[the affordance of something does not change as the need of the observer changes. The observer may or may not perceive or attend to the affordance, according to his needs, but the affordance, being invariant, is always there to be perceived. An affordance is not bestowed upon an object by a need of an observer and his act of perceiving it. The object offers what it does because it is what it is. (Gibson, 1986, p. 138-139)]

So, affordances are invariant and do not change according to the needs of the observer. Instead it is a matter of perceiving or paying attention to (or not) the existing affordances. Gibson also emphasises the role of the body in perceptual activity, and which affordances an animal perceives is related to its movements. The ambient light converges on a point of observation, but as an animal moves around its point of observation constantly changes, and so does the perceived pattern of light. Subsequently, a certain point of observation may or may not be occupied by an observer, but the affordances themselves always remain there to be perceived. While affordances are objective properties of the environment, in the sense that they are in the physical world, perceived affordances are subjective, in the sense that they depend on the context of a subject’s activity (Mace, 1977). For instance, whether an animal perceives that a gap can be jumped over or not depends on whether it is standing beside the gap, or if it is running towards it. Sometimes affordances can be misperceived, that is, we may fail to perceive what is present or perceive something not present, both of which are cases of misperception (Gibson, 1986). For instance, studies concerning a “visual cliff” by Gibson and Walk (1960, in Gibson, 1986), showed that infants still perceived that the cliff afforded falling off, even when a sheet of glass was extended out over the edge. Likewise, we may not perceive (or misperceive) a closed door that is made of glass, and walk right into it.

In addition to perceived affordances of objects, and similar to Heidegger’s point of second-hand knowledge of functionality, Gibson pointed out that
our use of objects is affected by social norms and experiences, and knowledge of conventional ways of using an object. For instance, above a certain age everyone knows the purpose of a mailbox. Furthermore, at the social level there is an enormous complexity of affordances and, in Gibson’s view, the richest and most elaborate affordances for humans are provided by other people.

In conclusion, Gibson opposes the subject-object dichotomisation and instead emphasises the reciprocal relationship between subject and object, where each subject lives in its own niche, or set of affordances. Information about the environment, its affordances, is made available in the perceived patterns of light that are reflected from surfaces. Hence, affordances are objective properties in the environment, objective in the sense that they are invariant and always there to be perceived. Even though a user’s needs may change, the affordances do not. However, affordances are always in relation to the subject, and the subject’s bodily movement is crucial for the perceptual activity.

3.1.4 Summary
At first glance the different perspectives (Sections 3.1.1-3.1.3) have clear similarities, but a closer investigation reveals they also have significant differences. Common to von Uexküll, Heidegger, and Gibson is the avoidance of a dualistic view of subject and object as two distinct entities. Both von Uexküll and Gibson emphasise the reciprocal relationship between an animal and its environment. In von Uexküll’s view each animal lives in its own niche, or subjective Umwelt, and Gibson considers each animal as having its own niche consisting of a set of affordances. Similarly, Heidegger argues that subject and object cannot be viewed as two separate entities as they are strongly interdependent, both of them meaningful only within a referential whole. Heidegger also strongly opposes the idea of some kind of mental mediation (intentionality, representations, etc.) between subject and object. Likewise, in Gibson’s view, there are no intermediary links between subject and object, in this case some psychological process between perception and cognition. Instead, Gibsonian ecological psychology considers perception as direct (however, see Costall, 1989) on the directness of perception).

Another similarity between von Uexküll and Gibson is the distinction between the physical environment and the perceptual world. However, there is a crucial difference in where they consider information to be ‘located’. In von Uexküll’s view, objects are meaningless entities since objects in themselves do not have any properties, and as such they are discarded by an animal. However, as an animal enters into a relationship with an object it ascribes some meaning to the object, which then becomes a meaningful entity that assumes a functional tone. Which functional tone it assumes depends on the subject’s needs or prevailing mode. Through such relationships the animal forms its own subjective universe. In Gibson’s view, on the other hand, an animal’s perceived environment consists of a set of affordances, which are objective properties found in the environment, and
they are specified in the ambient light. Hence, information is ‘located’ in the environment. In contrast to functional tone, affordances are invariant, always there to be perceived and objects do not “assume” affordances, nor are affordances bestowed upon objects according to an observer’s needs.

These perspectives differ in their view on the body’s role in the relation between subject and object. In Heidegger’s work the role of the body is perhaps most apparent in the emphasis on object manipulation, through which a subject gains first-hand understanding of what an object is for. In Gibson’s ecological perspective, tools (temporarily) extend the subject’s action-perception capacities. Furthermore, affordances are always perceived from a certain point of observation. As the subject moves around, its point of observation changes and, hence, affordances are related to the subject’s bodily movements. In von Uexküll’s work the body firstly determines what the organism can sense, and subsequently its perceptual world. Furthermore, the subject’s prevailing mood, presumably strongly dependent on the bodily state, determines the functional tone of an object. For instance, in the case of a crab’s hunger, a sea anemone may assume a feeding tone. Likewise, a rock, large enough to sit on, may assume a sitting tone if a person needs to rest his/her feet, but if the subject aims at throwing something at a barking dog the same rock does not assume a throwing tone because it is too heavy to throw.

An important difference in the views discussed here concerns the matter of context dependence. Heidegger considers equipment as meaningful only within the context of its use, through which an object is what it is. The functional tone of an object is also context dependent, as seen, for instance, in the case of a stone that can assume a path-quality or a throw-quality, depending on the subject’s prevailing mood. Affordances, on the other hand, are context independent as they are invariant and do not change as the needs of the observer changes. Yet, at the same time, affordances may be seen as context dependent as they are taken with reference to an animal and its point of observation. Considering that an animal moves around, the perceived affordances constantly change and which affordances it perceives depends on what it is presently doing, as in the case of standing by or approaching a gap. Another aspect of context in-/dependence is the social and cultural practices of the agent’s environment, which play some role in understanding what an object is and what it is used for. Heidegger and Gibson both emphasised that understanding objects and their use partly depends on social norms and knowledge of conventional ways of how to use an object. However, Gibson has also been criticised for treating “culture as merely a kind of potentially distorting screen partly interposed between us and an independent, ‘real’ world” (Costall, 1989, p. 19). Von Uexküll, focusing on the role of the body and each animal’s subjective construction of its world, did not include socio-cultural aspects of context in this niche construction.

An important point here is that phenomena that might be better explained in other terms, are often conflated under the term of ‘affordance’. As an
example, ‘misperceived affordances’ of functionality may in fact be a question of technology attributed with different functional tones by different users, rather than not perceiving the ‘affordances’ correctly. Similarly, in artificial intelligence and robotics the term affordance is commonly used to refer to some internal mechanism or construct, for instance, in phrases like “learning an affordance” or “representing an affordance” (see, e.g., Cos-Aguilera et al., 2003; Stoytchev, to appear; 2005; Valpola, 2005). Such descriptions are more compatible with von Uexküll’s view of functional tones as subjective constructions, than with the Gibsonian notion of affordances as directly perceived and ‘located’ in the environment. The case of artificial subjects’ (systems’) affordances also illustrates the fact that Gibson’s notion of affordances as being invariant, and independent of whether they are perceived or not, is not unproblematic. If, for example, some time in the future somebody would build a robot big and strong enough to grasp and lift a car, we would have to say that a car already affords grasping and lifting even though no such robot yet exists. That means, if we take Gibson seriously on this point, the world is already full of affordances for any number of future subjects that still have to be constructed or evolve naturally.

As a concluding remark, let us turn to Morris (2005), who points out an important limitation in Heidegger’s work. According to Morris, Heidegger (and Mearly-Ponty) took great care not to separate a subject from its environment. Nevertheless they made the mistake of considering humans in relation to other humans, while animals were considered as isolated individuals. This point also applies to von Uexküll’s Umwelt description as well as Gibson’s affordances. What is missing is a realisation that the lone animal is but an abstraction; animals, even those driven by instinct, are coupled to other animals. Morris (2005) argues that comparisons between humans and other species are prejudiced, and there is a pre-scientific presupposition of a distinction between humans and animals (further discussed in Chapter 4, on animal tool use). Typically in comparative studies, humans are compared to the individual animal, rather than humans or animals in groups, even though group behaviour differs from that of the individual. The individual animal’s behaviour is also affected by its environment, and as Morris points out, even as Heidegger (and the others mentioned above) is cautious not to separate an animal from its environment, it is remarkable that they focus on solitary animals. The idea of a lone animal is a construction that really has no equivalence in nature. Although some animal, for instance, ‘the lone wolf’ or a caterpillar, do not seem to coordinate their behaviour with others (i.e., no group-life is visibly apparent), they “live in populations that collectively transform ecological niches in ways that implicate their lives in one another’s behaviour” (p. 55). The way individual animals affect others is exemplified by a pack of wild

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28 As an example, Euro-American primatology has focused much on the individual’s achievements, while Japanese primatology instead has studied groups of individuals (de Waal, 2001; Morris, 2005).

29 Exceptions of “the lone animal” noted by Morris are the ones in zoos and houses, or, for instance, a dying wild animal.
dogs hunting a rabbit; while each individual dog follows its own trajectory, guided by instinct, together they exhibit skills of coordinated hunting and act on these instincts as a pack. Even though the dogs follow their instinct, their behaviours are diversified by ‘spatial distribution and temporal lags’. The coordinated pack behaviour can be seen as a kind of an improvisation “governed by the way differences insert themselves in instinctual dog-rabbit captivation, when a rabbit ropes dogs together and drags them dispersively through a landscape” (p.63). Therefore, as Morris points out, and quoted in length below, collective behaviour differs from that of the individual, and there is a sort of creativity or generality that erupts in animal behaviour when their bodies couple. Such coupling, which is necessarily spread out, introduces spatially and temporally distributed differences into a network of coupled instincts. An individual animal is exquisitely evolved to resonate a limited set of notes in its environment, and so it seems captivated with its environment. But when the animal couples with others, its environmental resonance is broken because it is no longer acting on its own, it is resonating to other locations in terrain and moments in times, it gets caught in a larger melodic. Where an individual animal is captivated with a few resonant notes, group animal movement can break this resonance up and read a new melodic in collective environmental interactions. Without our having to say that animals explicitly know how to or aim at doing what they are doing, animals, in their collective movement can enact something like the transition between sounding isolate notes and linking notes in a musical system. That is, animals can do something that amounts to ‘reading’ a new sense of their environment. Conceptually, the interesting thing is that this sense results from a coupling of individual animal-environment resonances, a coupling that results in frictions and lags, and thence in a breakage of those otherwise captivating resonances. (pp. 63-64)

According to Morris’ account, then, there is a difference in ‘isolate notes’ and the ‘larger system of melodic’ they form, an issue we will return to in Chapter 4, which describes animal tool use. First however, in the following three sections I will address cultural-historical theories, which are also concerned with the relationship between agents and their environments.

### 3.2 Cultural-historical theory of development

This section outlines the cultural-historical theory of development as formulated by Vygotsky (1896-1934). In his work, Vygotsky had as a goal the reformulation of a psychological theory along Marxist lines as opposed to the conflicting schools that dominated psychology at the time. Most dominating were Bekhterev’s reflexology, Pavlov’s physiology, and Kornilov’s reactology, which were soon to be joined by Vygotsky’s cultural-historical theory of development. He sought to synthesise different disciplines in what might be described as an interdisciplinary educational psychology, or pedology (Kozulin, 1986). Vygotsky’s primary concern was to describe

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30 As Grigorenko and Kornilova (1997) put it, by the early 1920s, a psychologist could either follow the Marxist orientation or be exiled or subdued.

31 In Soviet psychology pedology was considered as a multi-disciplinary science embracing physiology, defectology, psychology, and pedagogy. With the decree of pedology in 1936, pedology was abolished as a discipline and all forms of intelligence testing were forbidden. As a main proponent of pedology, and with an interest in testing, Vygotsky’s name was put
those aspects of development that are uniquely human (Vygotsky, 1925/1979, 1934/1986, 1978). He repeatedly compared primate research (e.g., by Köhler and Yerkes) and child development, and while recognising the similarities in man and animal, he especially focused on their differences. He also argued that “the most important way of explaining (as opposed to simply describing) human mental processes is to examine their origins and development”, and he considered the developmental method as “the central method of psychological science” (Wertsch, 1981, p. 26-27). Wertsch (1985) describes Vygotsky’s theoretical approach in terms of three themes that form the core of the approach:

(1) a reliance on a genetic or developmental method; (2) the claim that higher mental processes in the individual have their origin in social processes; and (3) the claim that mental processes can be understood only if we understand the tools and signs that mediate them. (p. 14-15)

According to Wertsch, the concept of mediation is Vygotsky’s most important contribution, and it became increasingly important in Vygotsky’s work during the last decade of his life. Although Vygotsky’s main preoccupation was the role of language and speech in human activity, he recognised and described the importance of material as well as psychological tools as mediational means.

3.2.1 Tools and mediation
Vygotsky (1978) considered tools and human speech the two major cultural mediators. Mediation is essential in the development of higher forms of mental functions or higher psychological activity. Mental functions, like perception, attention, will, and memory, first appear as elementary functions, and then transform into higher, or cultural, mental functions. Vygotsky explained the difference between elementary and higher mental functions, in the case of memory, as there being two forms of memory, viz., natural memory and memory mediated by signs. Natural memory is “close to perception, because it arises out of the direct influence of external stimuli upon human beings” (1978, p. 39). The higher form of memory, on the other hand, has social origins and is mediated by signs. In Vygotsky’s (1934/1986) words,

higher form of intellectual activity, is not a quantitative overgrowth of the lower associative activity, but a qualitatively new type. Unlike the lower forms, which are characterized by the immediacy of intellectual processes, this new activity is mediated by signs. (p. 109)

While Vygotsky agreed with the Pavlovian idea that signalisation is the fundamental and most general basis of behaviour in higher animals and man, he argued that signification (i.e., the creation and use of artificial signs) is the most fundamental activity distinguishing man, psychologically, from animal (1960/1977). The difference in elementary and higher functions is explained as a difference in the structure of the stimulus-response relations on the black list, and his work was banned until the late 1950s (Grigorenko & Kornilova, 1997; Haenen, 1996a; 1996b).
of each (Vygotsky, 1978). The elementary forms of stimulus-response behaviour, which can be expressed in the form of \( S \rightarrow R \), are directly determined by environmental stimuli. The structure of sign operations, on the other hand, requires an intermediate link to create a new relation between the stimulus and the response, namely, a second order stimulus, or sign. Thus, the \( S \rightarrow R \) process was replaced by a mediated act (Figure 3). Importantly, the intermediate link (the sign) does not operate on the environment, but on the individual, and it “leads humans to a specific structure of behavior that breaks away from biological development and creates new forms of a culturally-based psychological process” (Vygotsky, 1978, p. 40).

![Figure 3](image)

**Figure 3.** The process of a mediated act (redrawn from Vygotsky, 1978).

This new intermediate link in the mediated act changes the whole structure of the psychological process:

The inclusion of a [psychological] tool in the process of behavior (a) introduces several new functions connected with the use of the given tool and with its control; (b) abolishes and makes unnecessary several natural processes, whose work is accomplished by the tool; and (c) alters the course and individual features (the intensity, duration, sequence, etc.) of all the mental processes that enter into the composition of the instrumental act\(^{32}\), replacing some functions with others (i.e., it re-creates and reorganizes the whole structure of behavior just as a technical tool re-creates the whole structure of labor operations). (1960/1981, pp. 139-140)

Besides the sign, acts are also mediated by another auxiliary means; material tools. Both sign and tool have a mediating function, and their logical relationship is expressed as seen in Figure 4, where both concepts are subsumed under the more general concept of mediated activity.

![Figure 4](image)

**Figure 4.** Sign and tool subsumed under the concept of mediated activity (redrawn from Vygotsky, 1978).

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\(^{32}\) Minick (1996, p. 28) describes the ‘instrumental act’ as “a unit of activity mediated by signs that are used as tools or instruments to control behavior” (Vygotsky focused on the instrumental act as an analytic unit during 1925-1930).
Signs are analogous to tools in the sense that they act as instruments of psychological activity, just as tools act as instruments in labour (1960/1977). Yet, while sign and tool share a basic analogy, they cannot be equated or considered isomorphic since their fundamental distinction would be erased and the specific characteristics of each type of activity would be lost. According to Vygotsky (1978), the most essential difference between the two lies in the different ways they orient human behaviour:

The tool’s function is to serve as the conductor of human influence on the object of activity; it is externally oriented; it must lead to changes in objects. It is a means by which human external activity is aimed at mastering, and triumphing over, nature. The sign, on the other hand, changes nothing in the object of a psychological operation. It is a means of internal activity aimed at mastering oneself; the sign is internally oriented. These activities are so different from each other that the nature of the means they use cannot be the same in both cases. (p. 55)

Even though sign and tool use differ, Vygotsky argued they are mutually linked. He also criticised research that considered sign use (speech) and tool use as separate processes, and maintained that although they are initially independent lines of development, and can operate separately in young children, their convergence is “the most significant moment in the course of intellectual development” (p. 24). While focusing on child development, he also recognised that “the dialectical unity of these systems [sign and tool use] in the human adult is the very essence of complex human behaviour” (Vygotsky, 1978, p. 24, emphasis added).

Evidently, tools have a profound impact on human behaviour as they affect our cognitions and alter our behaviour altogether. In Vygotsky’s writings on regarding tools, we also see a description of what is now generally termed ‘cognitive artefacts’, a description that appeared long before the concept appeared in contemporary cognitive research (cf. Section 2.3). The use of cognitive artefacts truly demonstrates that tool use allows humans to “control their behavior from the outside” (1978, p. 40).

As seen so far, tools are an important part of human activities. However, tools not only change people’s behaviour, they also have an important role in the formation of a child’s mental processes, as shown in the next subsection.

### 3.2.2 Internalisation and the zone of proximal development

Central to Vygotsky’s approach is the process of internalisation, which relates internal and external activities. In his view, “the internalization of cultural forms of behavior involves the reconstruction of psychological activity on the basis of sign operations” (1978, p. 57). Two such cultural forms of behaviour arise during infancy, viz., tool use and speech. The process of internalisation includes a series of transformations, and it emphasises the social dimension of development. In the general genetic law of cultural development, Vygotsky explained that “[e]very function in the child’s cultural development appears twice: first on the social level, and later, on the individual level; first between people (interpsychological), and then inside the child (intrapsychological)” (Vygotsky, 1978, p. 7). This general law
applies to higher functions like memory and concept formation. In his later work, Vygotsky addressed the issue of scientific concept formation in children, in the context of school instructions. Such instructions, or cultural cognitive tools, may take on a variety of forms, for instance, as concepts, criteria, schemas, or models. Vygotsky argued that we need to understand the development of scientific concepts in the child, thereby gaining the possibility to devise successful methods of instruction for the schoolchild (Vygotsky, 1934/1986; 1934/1987). In other words, proper instruction is needed to facilitate the child’s learning in the best possible way. As such, school instructions provide a good example of how material tools can affect cognition. The consideration of instruction and concept formation also points to the fact that Vygotsky’s approach included, although perhaps not explicitly stated by himself, the idea that “the quality of acquired cultural tools crucially affects the child’s development” (Arievitch & Stetsenko, 2000).

Vygotsky (1934/1987) and his colleagues empirically investigated the development of scientific (‘true’) concepts in comparison with everyday concepts (‘spontaneous thinking’). From the study they concluded these different kinds of concepts develop differently (Vygotsky, 1934/1986):

In the case of scientific thinking, the primary role is played by initial verbal definition, which being applied systematically, gradually comes down to concrete phenomena. The development of spontaneous concepts knows no systematicity and goes from the phenomena upward toward generalizations. The scientific concepts evolve under the condition of systematic cooperation between the child and the teacher. Development and maturation of the child’s higher mental functions are products of this cooperation...Scientific concepts develop earlier than spontaneous concepts because they benefit from the systematicity of instruction and cooperation. (p. 148)

Despite the distinction between the two kinds of concepts, Vygotsky (1934/1986) considered the processes of their development as interrelated, constantly influencing each other, and as part of the single process of concept formation. Furthermore, Vygotsky considered this interrelation as a special case of a broader subject, that of the relation between school instruction and the mental development of the child. He further argued that the study of scientific concepts has important implications for education and instruction, because a child does not absorb ready-made concepts, instead instruction and learning have a leading role in the acquisition of concepts. In formulating a theory of the relation between instruction and development, Vygotsky (1934/1986) and his colleagues conducted a series of investigations in the context of formal schooling. The investigations concerned school instruction in subjects such as reading and writing, grammar, arithmetic, natural science, and social science. They concluded that “the development of the psychological foundations of instruction in basic subjects does not precede instruction, but unfolds in a continuous interaction with the contributions of instruction” (1934/1986, p. 184).

At the time, most psychological investigations measured the level of a child’s mental development by having the child solve standardised problems. That, however, measured only a completed, matured part of development, and only
the actual level of the child’s development could be determined (1934/1987). In Vygotsky’s view, psychological analysis cannot be limited to the functions that have already matured, rather it has to consider the zone of proximal development, i.e., the distance between “the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers” (1978, p. 86).

The interaction between child and adult in the zone is not merely social transmission of cognitive skills that would imply some cognitive leap in the child’s development, nor is the development a result of some sudden insight, as argued by some critics, e.g., Lockman (2000). On the contrary, Vygotsky (1978) criticised the view of sign use development as an example of pure intellect and not as the product of the child’s developmental history, and he specifically pointed out that

it would be a great mistake...to believe that indirect [mediated] operations appear as the result of a pure logic. They are not invented or discovered by the child in the form of a sudden insight or lightning quick guess (the so-called ‘aha’ reaction). The child does not suddenly and irrevocably deduce the relation between the sign and the method for using it. (p. 45)

Thus, even though Vygotsky viewed psychological development as a dynamic process with sudden changes (Kozulin, 1986; Vygotsky, 1960/1981b), it was not considered as linked to cognitive leaps or sudden insights. He also criticised research that studied different processes as isolated phenomena (cf. Section 3.2.1), and instead emphasised the interrelatedness of the processes involved in a task:

children solve practical tasks with the help of their speech, as well as their eyes and hands. This unity of perception, speech, and action, which ultimately produces internalization of the visual field, constitutes the central subject matter for any analysis of the origin of uniquely human forms of behavior. (1978, p. 26)

Thus, Vygotsky’s developmental perspective is more in line with, for instance, Lockman’s own action-perception view, than a ‘representational’ view, as Lockman claims (cf. Section 3.1.2). Moreover, Vygotsky argued that “sign-using activity in children is neither simply invented nor passed down by adults” (Vygotsky, 1978, p. 45). Rather, both the child and its environment are active (cf. Cole & Griffin, 1980; Cole & Wertsch, 1996).

In Vygotsky’s (1978) view, instruction should not address the actual level of development. Rather, to be useful, they need to address the maturing processes within the zone. Subsequently, instruction was considered useful only when it ‘moved ahead’ of development, in which case it “impells or wakens a whole series of functions that are in a stage of maturation lying in the zone of proximal development” (p. 212). And this, he concluded, “is the major role of instruction in development” (ibid.).

Thus, according to Vygotsky (1934/1987, p. 210), central to psychological studies of instruction is “the analysis of the child’s potential to raise himself
to a higher intellectual level of development through collaboration, to move from what he has to what he does not have”. As seen in the above, social interaction and the quality of instruction are central for learning in the zone of proximal development. However, even though Vygotsky saw instruction and development as interrelated processes, he did not specify the relation between the particular content of instruction and development (Arievitch & Stetsenko, 2000). This relation was later elaborated by Gal’perin, who focused on the formation of mental actions on the basis of external tools, which is further discussed in Section 3.4.

The idea of internalisation later developed into two different forms. While Vygotsky was “interested in the problem of internalisation of symbolic psychological tools and social relations”, others studied “internalisation as the process of transformation of external actions into internal psychological functions” (Kozulin, 1986, p. 26). Such external actions involve the use of various kinds of tools, such as school instructions. This issue is revisited later (in Section 3.4) when describing the work of Gal’perin, who elaborated some of Vygotsky’s ideas as well as some ideas in activity theory, to which we next turn.

### 3.3 Cultural-historical Activity Theory

This section describes cultural-historical activity theory (AT), a theory of human activity which focuses on understanding the individual, other people, and artefacts in everyday activity, as well as their interrelatedness. In the following, focus will be on the concept of activity, the structure of activity, the theory’s basic features, and the activity model.

Activity theory is a cultural-historical theory of human activity, and many researchers have contributed to its formulation, among them Vygotsky, Leontiev, and Luria. While the theory’s origins have been much debated, its formulation is commonly ascribed to A.N. Leontiev, who was one of Vygotsky’s first students. Leontiev formulated the theory’s basic principles in the 1960s and 1970s, although the first outlines were seen in his writings in the 1930s and 1940s (Kaptelinin, 1996b; Kozulin, 1996). Most of the major features of activity theory had in fact been outlined in the 1920s and 1930s in the writings of Vygotsky and others. For instance, the concept of activity was important in Vygotsky’s work, even though he focused on other aspects and never fully analysed it. Central to his work were also the ideas of the social origins of cognition, the role of sign systems as mediators in human thinking, and internalisation, concepts that also became important in activity theory (Wertsch, 1981). However, Leontiev has been the main figure in consolidating and integrating the ideas of Vygotsky and others into the theory of activity, and he also made some genuine contributions of his

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33 Nowadays several interpretations and variations of activity theory are available. The description in this section is based primarily on Leontiev’s and Engeström’s writings.

34 Vygotsky and Leontiev were close co-workers from the mid 1920s until the early 1930s, when Leontiev’s criticism of Vygotsky’s work caused them to go separate ways (Haenen, 1996a).
A central theme in Soviet psychology in the 1920s and 1930s (and a long time thereafter) was the relation between consciousness and activity (see e.g., Gal'perin, 1977/1992; Haenen, 1996a; Wertsch, 1981). At the time Soviet psychology was dominated by several conflicting schools and heated debates were common between proponents of different approaches. One of the first postulates agreed upon by the psychologists was the inseparability of consciousness and activity (Kaptelinin et al., 1995), which is one of the main ideas in activity theory. The notion of this inseparability stems from S.L. Rubinshtein (1889-1960) who sought to explain the relation between consciousness and the material world. Working on this issue, he introduced the notion of activity and stressed that activity is not just external behaviour, it is inseparably linked with consciousness (Wertsch, 1981). Subsequently, the human mind cannot be isolated and studied separately. According to this view, every activity has both an internal and an external aspect, and the relationship between subject and object is reciprocal where one transforms the other. Hence, a dualistic view of an isolated, independent mind is unacceptable within activity theory.

Another main idea in activity theory is the social nature of all human activity. Vygotsky, for instance, had emphasised that social interaction is the basis for development of word meaning. However, in Leontiev’s view, social interactions cannot explain the cause of development, and therefore he considered Vygotsky’s approach to psychology too narrow to be able to explain consciousness (Haenen, 1996a). Furthermore, Leontiev considered individual object-oriented action mediated by tools and signs (Figure 5) insufficient as a unit of analysis since all human activity is co-operative. Nevertheless, the notion of tool-mediated and object-oriented action forms a basic concept of activity theory.

Figure 5. The structure of an action and the tool-mediated relationship between humans and objects (modified from Kuutti, 1996).

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35 The concept of consciousness, as used in Soviet psychology, has a quite different philosophical foundation than in Western psychology, and is therefore conceived differently (see e.g., Galperin, 1977/1992; Haenen, 1996a; Wertsch, 1981). However, with more recent developments of activity theory in different disciplines, much simplified ways of describing consciousness have appeared. For instance, Nardi (1996, p. 7) describes consciousness as being “located in everyday practice: you are what you do”, which seems rather vague. Nardi’s expression is similar to the first proposition (expressed in the 1920s) towards an understanding of consciousness, even though not yet psychology: “as is the way of life, so is consciousness” (Galperin, 1977/1992).
Leontiev’s starting point was to replace Vygotsky’s sign (or tool) as an intermediate link between subject and object. In its place, Leontiev invoked the notion of activity, thereby extending the basic structure of action, arguing that consciousness originates from external activity (Leontiev, 1972/1981). Subsequently, Leontiev began to “analyze consciousness, activity and external objects as a unified system” (Haenen, 1996a, p. 82).

3.3.1 The structure of activity
Central to activity theory is the notion of activity, the philosophical roots of which are found in the works of Marx, Engels, and Lenin (Engeström & Miettinen, 1999; Wertsch, 1981). Marx argued that human agency cannot be explained by idealism or materialism, since both of them lack the concept of activity. Activity overcomes this dualism, and provides a new way of understanding change. Central to Leontiev’s formulation of activity was Marx’s concept of labour as a model of human object-oriented activity (Engeström & Miettinen, 1999). Leontiev also emphasised (based on Marx and Engels) two aspects of mediation in labour activity: the making of tools and their use, and the collective nature of activity. The latter aspect helped Leontiev to distinguish between individual actions and collective activity (further explained below).

Considering human activity, it begins with labour, which has been defined as “a process in which both man and Nature participate, and in which man of his own accord starts, regulates, and controls the material re-actions between himself and Nature” (Tolman, 1999, p. 71, citing a classical definition by Marx). Labour could be, and often is, defined in terms of use and making of tools, but that would not be sufficient for defining the process of human labour (tool use among chimpanzees was known already in the days of Marx, cf. Chapter 4). Instead, Marx emphasised individual consciousness and the collective nature of activity, ideas that Leontiev brought into activity theory. As (shared) activities are made up of individual actions, they must be accompanied by a shared meaning that is consciously reflected upon by the individual (Tolman, 1999), which is well illustrated by Leontiev’s renowned example of the beater in a primitive collective hunt (Engeström & Miettinen, 1999; Tolman, 1999). The beater requires food for survival but his actions, for instance, driving the prey toward the other hunters, seem to oppose his immediate need. Considering the beater’s actions in isolation they make no sense, instead their sense lies in his relation to the other hunters, since he knows someone is waiting at the other end to achieve his goal. This example also illustrates the co-operative nature of human activity, which is why Leontiev considered individual tool-mediated action (the instrumental act) as a unit of analysis to be insufficient (Engeström, 1987). In order to understand the individual’s actions, they have to be considered in the context of the overall collective activity, since “human labor…is co-operative from the very beginning. We may well speak of the activity of the individual, but never of individual activity; only actions are individual” (Engeström, 1987, p. 66). Having distinguished individual

Whether individuals taking part in shared activities are always actually consciously aware of a shared meaning may not be all that clear (see, e.g., Susi & Ziemke, 2001).
actions and collective activity, Leontiev (1972/1981; 1978) formulated a hierarchical structure of activity, which also serves as a unit of analysis.

Vygotsky founded analysis of activity as a method of psychology by introducing the concepts of tool, tool operation, goal, and motive (Leontiev, 1972/1981). Leontiev integrated these concepts, and devised a three-level hierarchical structure of activity, in which he distinguished activity, action, and operation, related to motive, goal and condition, respectively (Figure 6). Activities are undertaken in order to fulfill some motive. Actions (what must be done) are processes subordinated to activities, and they are directed at specific conscious goals. As expressed by Wertsch (1981): “the level of abstraction in the theory of human activity that deals with actions is concerned with conscious goals”. Operations (how it can be done) are functional subunits of actions, defined by the prevailing conditions or circumstances under which they are carried out. Operations do not have their own goals, instead they provide an adjustment of actions to current situations. Operations are often transformed actions; while actions have explicit goals that are performed consciously from the beginning, they are transformed into operations through learning. The difference between actions and operations is not always easily distinguished. However, according to Leontiev (1972/1981, p. 63), their difference “emerges especially clearly in the case of actions involving tools, after all, a tool is a material object in which methods or operations, rather than actions or goals, are crystallized”.

![Figure 6](image)

**Figure 6.** The three levels of activity, exemplified by driving a car (illustration modified from Kuutti, 1996).

During an ongoing activity there are constant transformations between the different levels, which Leontiev (1972/1981) illustrates by the driving a car example:

Initially, every operation – for example, shifting gears – appears as an action subordinated to a goal...Subsequently, this action is included in another complex action, such as that of changing the speed of the automobile. At this point, shifting gears becomes one of the methods for carrying out this action – that is, it becomes an operation necessary for performing the action. It is no longer carried out as a special goal-directed process. The driver does not distinguish its goal. So far as the driver’s conscious processes are concerned, it is as if shifting gears under normal circumstances does not exist. He/she is doing something else: he/she is driving the automobile from place to place...Indeed, we know that this operation can ‘drop out’ of the driver’s activity entirely and can be performed automatically. (p. 64)
Although operations ‘drop out’ and become automatised, they may, under certain circumstances transform into conscious actions again. For instance, in the driving a car example, the driver might change to an unfamiliar car in which the gears have a different order (which is quite common) than those he is accustomed to. The shifting of gears then becomes an action since it requires conscious attention. Once the new car becomes familiar the shifting of gears is transformed back to an operation again.

Although activities are differentiated into three levels, they cannot be analysed as separate entities with no consideration of their internal relations, since (as shown above) activities are characterised by continuously proceeding transformations (Leontiev, 1978). Hence no part can be regarded in isolation, for instance, in Leontiev’s words, “a tool viewed apart from a goal becomes just as much an abstraction as an operation viewed apart from the action that it implements” (1972/1981, p. 65). Similarly, as expressed by, for instance, Ingold (1993b), in order to understand artefacts and tools we need to attend to the context of their use (cf. Section 2.3.2).

3.3.2 Main features of Activity Theory

Activity theory is most often described in terms of some main features, or basic characteristics. One of them is the hierarchical structure of activity, as discussed in the previous section. Other main features include object orientation, mediation, developmental or genetic explanation, and internalisation/externalisation. Object orientation means that activities are always directed towards an object, and each activity is distinguished from others according to their differing objects (Leontiev, 1972/1981). As expressed by Leontiev (1978, p. 62): “[i]t is exactly the object of an activity that gives it a determined direction”. Leontiev further argues: “the object of an activity is its true motive” (ibid.). In other words, behind the activity there is always some need to answer to, and the motive may be material (a human or a physical object) or ideal (mental), “either present in perception or existing only in the imagination or in thought” (ibid.). Commonly, the object of activity is termed its objective. However, the term ‘objective’ may cause some confusion since it refers to, on the one hand, what an activity is directed towards, and, on the other hand, the ‘lived in objective reality’. Regarding the ‘objective reality’, Kaptelinin et al. (1995; for further discussion, see Leontiev, 1972/1981) explain:

On the one hand, Activity Theory is based on the materialistic philosophy of Marxism, and it assumes that human beings live in objective reality which determines and shapes the nature of subjective phenomena. This basic assumption makes it possible to seek for an objective account of subjective phenomena. Psychology, according to Leontiev, can be (and should be) no less a thorough, rigorous science than natural sciences are. On the other hand, Leontiev clearly understood that the concept of object in psychology cannot be limited to physical, chemical, biological, etc., properties of things. Socially determined properties of things, especially those of artifacts, and the very involvement of things in human activity, are also objective properties which can be studied with objective methods. So, the principle of object-orientatedness states that human beings live in a reality which is objective in a broad sense; the things which constitute this reality have not only the properties which are considered objective
Another main feature of (object-oriented) activities is the concept of mediation, i.e., the tools that mediate our actions. The notion of mediation by tools was introduced by Vygotsky; humans create stimuli, psychological or material, that determines their own reactions and is used as means for mastering their own behaviour (cf. Section 3.2.1). Vygotsky claims that tools are mediators of human thought and behaviour, and there is a mediated relationship between subject and object. Mediators can be anything used in the transformation process, for instance, technical tools, signs, symbols, language, procedures, methods, laws, and forms of work organisation (Kuutti, 1996). All artefacts have a socio-cultural history, that is, the social and cultural knowledge of a society becomes built into the artefacts we modify, develop, and use. Thus the tools we use in our everyday activities become transformed and the historical development of an artefact is crystallised in the artefact (Leontiev, 1972/1981). However, the use of tools not only transforms the objects themselves, rather it is a ‘two-way process’, as expressed by Raeithel (1992, p. 397): “[o]bject-oriented activity creates a world full of new objects that physically exist as the material heritage that the next generation has to cope with, and by which the activities of elders and children alike are transformed...in turn”.

Activity theory is characterised by taking a developmental or genetic explanation to activities. Human practices do not emerge as ready formed activities, rather they develop over time, and all human practice is being shaped and reformed by historical development. Thus, rather than analysing some activity at one instant in time, it has to be examined in the context of development (Kaptelinin et al., 1999). With regard to mental processes, for instance, they must be examined in their phylogenetic, ontogenetic, historical and microgenetic path in order to gain explanatory power (Wertsch, 1981). This ‘developmental aspect’ also applies to tools, as activity theory emphasises the importance of understanding how their use unfolds over time, instead of considering the use of tools during a single observation. As explained above, tools may become more useful and efficient over time as knowledge accumulates in them.

Activities are characterised by continually operating processes of internalisation and externalisation. Internalisation refers to “the conversion of external processes with external material objects into processes carried out on the mental plane, on the plane of consciousness” (Leontiev, 1972/1981, p. 55). So, what is initially external may become internal. Internalisation, or ‘internal reconstruction of an external operation’ (Vygotsky, 1978), occurs, for instance, in learning by counting on one’s fingers (Vygotsky, 1978; Wertsch, 1981).
Once the counting is learned by heart the activity has become internalised, or mental. As a result of internalisation (in general), the processes involved become “generalised, verbalized, abbreviated...and they can be developed further...[which] allows them to exceed the limitations of external activity” (Leontiev, 1972/1981, p. 55). However, internalised processes may become externalised again. For instance, in the case of counting, if an arithmetic task too difficult to be solved internally is encountered, one’s fingers may become helpful again. Internalisation also provides a means for mental simulations, consideration of alternative plans etc., before actually performing with real objects (Kaptelinin et al., 1999).

3.3.3 The activity model
As discussed in the previous sections, Leontiev formulated a three-level model of human activity, which distinguished between activity, action and operation. It also distinguished between individual action and collective activity, which was illustrated by the example of the collective hunt (Section 3.3.1). Leontiev’s model of collective activity has been illustrated by Engeström (1987) as a model of a collective activity system. Engeström devised his model of (human) activity by elaborating the animal form of activity. The general structure of the animal form of activity, what he calls the “general mode of biological adaptation” (p. 73), is depicted in Figure 7. Central to the model is the “immediately collective and populational character of animal activity” (p. 73). The collective and populational character of activity is also central in Engeström’s model of human activity (Figure 8). Animal activity is not regarded as just ‘passive acquiescence’ to nature, instead organisms and environments affect each other in several ways. According to Lewontin (in Engeström, 1987, p. 74), evolution cannot be regarded as “the ‘solution’ by species of some predetermined environmental ‘problems’ because it is the life activities of the species themselves that determine both the problems and the solutions simultaneously...organisms within their individual lifetimes and in the course of their evolution as species do not adapt to environments; they construct them” (regarding niche construction, see, e.g., Day et al. 2003; Laland et al., 2000).

![Figure 7. The general structure of animal activity (redrawn from Engeström, 1987).](image-url)
Regarding higher levels of animal evolution, Engeström describes each side of the triangle (above) as follows:

The uppermost side of ‘individual survival’ is ruptured by the emerging utilization of tools[^38], most clearly demonstrated by the anthropoid apes... The left hand side of ‘social life’ is ruptured by collective traditions, rituals and rules, originating at the crossing of adaptation and mating. The right hand side of ‘collective survival’ is ruptured by division of labor, influenced by the practices of breeding, upbringing and mating, and appearing first as the evolving division of labor between the sexes. (p. 74-75)

Prime examples of the ruptures of ‘tool use’ and ‘social life’ would be anthropoid apes and dolphins, respectively. There are some main differences however, between, as Keiler (in Engeström, 1987) describes it, ‘man and animal’, in that anthropoid apes, although a species that makes and uses tools, do not produce and preserve tools systematically; the making and use of tools are “exceptional rather than dominant forms of their activity” (p. 75). However, more recent primate studies indicate that albeit the making and use of tools among apes might not be a dominant form of activity, it is not exceptional, but a routine behaviour in their everyday activities (Gibson & Ingold, 1993; Whiten et al., 1999). Chimpanzees for instance do make and preserve tools systematically (Boesch & Boesch, 1993, see also Chapter 4).

As the separate ruptures (Figure 7) became ‘unified determining factors’ (along with other changing factors) a specifically human form of activity emerged (Engeström, 1987), depicted in Figure 8.

![Figure 8. Transition from animal to human form of activity](redrawn from Engeström, 1987).

The outcome of the transition (in modelling terms) is a structure of human activity, or an activity system (Engeström, 1999), as shown in Figure 9. This model is an extension of Vygotsky’s basic model of mediated action (Figure 5). According to Engeström (1987, 1999), activity and action had not been conceptually distinguished at the time Vygotsky presented the model. What was lacking in Vygotsky’s model was the relationship between an individual

[^38]: No definition is given by Engeström as to what is included in “tools” in animal activity. Applying a broad definition of tools, or artefacts, in animal activity, they would include objects like straws for fishing termites, use of hiding material for camouflage, use of shells for protection (Beck, 1980), chemical traces, and building material in ant or wasp nests (Karsai & Theraulaz, 1995) (further discussed in chapter 4).
and the environment, or the societal and collaborative nature of actions. In Engeström’s model of human activity, ‘community’ has been added as a third main component.

The model of human activity contains three mutual relationships between subject, object, and community. Tools are mediators between subject and object, while rules are mediators between subject and community. The relationship between object and community is mediated by a division of labour. A concrete example of an activity is provided by Kuutti (1996), who describes the work of a software development team; the activity consists of the team programming a system for a client. The object is the system, not yet ready, which is to be transformed into a delivered, complete application. The individual team members are the subject, and the whole team is the community sharing the object. There is a division of labour between manager and subordinates, between software developers and user representatives, and between the team members. A set of rules covers what it means to be a member of this community. Some of the rules are explicit, such as laws, and some may be implicit, like a working culture or rules that develop as the team works together. A number of tools and instruments are used in the transformation process, for example, analysis methods, computers, programming tools, walk-throughs or heuristics.

The activity model (as depicted by Engeström) has become a general unit of analysis in much cultural-historical research, and cultural-historical activity theory itself has come to form a theoretical framework in many different areas, such as education, human-computer interaction, computer-supported cooperative work, design, and systems development (e.g., Bannon & Bødker, 1991; Bødker, 1991, 1998; Engeström, 1987; Kaptelinin et al., 1995; Kuutti, 1996; Miettinen & Hasu, 2002; Raeithel, 1992; Verillon & Rabardel, 1995).

However, various kinds of criticism have also been formulated against activity theory. One of the major problems that AT has encountered coincides with Vygotsky’s criticism of mentalism, namely the problem of explaining a concept through the very same concept, for instance, to explain behaviour through behaviour, or consciousness through consciousness. In the case of activity theory, the concept of activity was used both as an explanatory principle and as a subject of study, meaning that “the phenomena of activity were ‘explained’ through the principle of activity”
This still seems to be an unsolved problem. Dichotomising the explanatory principle and subject of study does not, however, seem to provide a solution. Engeström (1999) argues that when activity is used only as an explanatory principle the outcome is often “an endless conceptual exercise with meagre empirical grounding” (ibid., p. 27), while empirical, practice-oriented research, with its specific methods and findings, may not contribute to elaborating the conceptual and methodological basis of activity theory.

Even harsher critique against AT has been brought forth, for instance, by Toomela (2000), who considers activity theory a dead end for cultural-historical research. According to him, activity theory does not explain the human mind and its genesis, and it considers individual psychological phenomena as only passive reflections of social activities. However, AT (and Soviet psychology in general) strongly emphasise the importance of active subjects, rather than considering humans as passively receiving input from the material and social environment (Cole & Wertsch, 1996; Gauvain, 2001; Leontiev, 1972/1981; Wertsch, 1981).

Davydov (1999) points to other problems concerning, for instance, the relation between collective and individual activity, or between collective and individual subject (cf. Susi & Ziemke, 2001). Commonly, activity theory admits that individual activity is formed on the basis of collective activity, i.e., through a process of internalisation. Lektorsky (cited in Davydov, 1999, p. 44) argues: “in a certain sense, the collective subject exists outside particular individual subjects and reveals itself through external, objective-practical, collective activity rather than through individual consciousness”. This gives rise to, e.g., the question of “What characteristics can help to distinguish collective and individual subjects?” (Davydov, ibid.). In a similar vein, Raeithel (1992) asks how we can describe the relations between individual human actors and social systems, both of which are considered as relatively autonomous. These questions do not yet have concrete answers in the activity theory community.

Davydov discusses several other problems which are not further described here (see Davydov, 1999), although one more point might be of interest. In Davydov’s view, we need an interdisciplinary approach for studying human behaviour, and activity theory should take into account other theories concerned with human behaviour as there are some close connections. Approaches to situated cognition, for instance, share many similarities with cultural-historical research, and research in both camps could benefit from considering the other (Arievitch, 2003). Other theories of interest include Piaget’s genetic epistemology and Gal’perin’s systematic formation (which is described in the next section), both of them based on actions and operations.

To summarise, Leontiev invoked activity (instead of sign) as an intermediate link between subject and object. Furthermore, by integrating different ideas (from Vygotsky and others), he worked out a three-level hierarchical structure of human activity. This structures also distinguished between
individual action and social activity. Activity theory emphasises the social nature of human activity and stresses the importance of considering activities in relation to cultural and historical aspects. It also emphasises the role of artefacts as mediators in human activities. Engeström elaborated and expanded the basic ideas of activity theory, and formulated a systemic model of activity. Some of the concepts of activity theory have been further elaborated in the work of Gal’perin, which is discussed in the following section.

3.4 Systematic formation of mental actions and concepts

This section describes the work of Piotr Gal’perin (1902-1988), who is mostly known for his method of stage-by-stage formation or systematic formation of mental actions and concepts, which has been described as a “teaching-learning experiment in which mental actions are formed with specific intended (prescribed and desired) properties” (Haenen, 1996a, p. 121). The two main sources of Gal’perin’s theory can be found in the works of Vygotsky and Leontiev. Gal’perin worked with them but came to criticise and depart from their views, to formulate his own theory of human mental activity. In Gal’perin’s view their theories were too all-embracing and he disagreed, for instance, with Vygotsky’s synthesising approach, arguing that “each science should remain strictly autonomous” (Haenen, 1996b, p. 55), otherwise the researcher would have to be an expert in all areas concerned.

Central issues for Gal’perin were the concept of activity and the origins of mind, as well as the nature of developmental cognitive processes, which he approached by studying “the process of internalisation of cultural tools as a specifically human form of the individual’s cognitive development” (Arievitch & Stetsenko, 2000, p. 73). In general terms, Gal’perin set out to find the ‘true subject matter of psychology’, that is, orienting activity. While Vygotsky had established the significance of orienting activity, by explaining the way humans control their behaviour ‘from the outside’ through the use of tools, he did not explain where the orienting activity comes from or how it emerges (Haenen, 1996a) (see Section 3.4.2). Gal’perin’s research into this issue led to a quite extensive theoretical framework of ‘systematic formation’. Not all of it, but rather some of the cornerstones of his theory will be described, with a focus on the role of instructions in the formation of mental actions. The following subsection explains parts of Gal’perin’s early work concerning tool use in children and apes, which presumably provided the foundation for his emphasis on mental actions as being material in their origin.

3.4.1 Development of tool use

Gal’perin experimentally investigated differences in tool use between humans and animals, and the development of human tool-mediated activity (Haenen, 1996a, pp. 32-37). Vygotsky had criticised the conclusions reached by

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39 Galperin probably would have approved of comparing theories, as proposed by Davydov in the previous section, but he would have been strongly against interdisciplinary studies.

40 This work is part of Galperin’s candidate dissertation from 1936. Most of this work only exists in manuscript form, and only a small part of it has been published. Subsequently, the present description on that part of Galperin’s work is mostly based on Haenen (1996a).
other researchers about similarities in tool use by children and apes. Instead of looking at similarities in man and animal, Vygotsky focused on the differences and considered signs, symbols, and particularly speech, as the most unique human tools. Gal’perin’s starting point was also the differences in humans and animals (see also Gal’perin, 1976/1992). However, in his view the specific content of practical activity was more crucial than speech, and he raised the question of how tool use influences the child’s practical activity.

In his early work, Gal’perin studied how children become familiar with common household tools like a spoon, a comb, and a hammer. Gal’perin claimed that such tools need to have a meaning for the child in the context of practical activity, but initially they have none. As long as the tool has no meaning it enters the child’s activity without changing the structure of the activity. However, as the child gains experience in using the tool, it reconstructs the child’s activity. Gal’perin termed inexperienced and experienced tool use as ‘manual operations’ and ‘instrumental’, or ‘tool-mediated operations’, respectively. He considered animal tool use as manual operations in which the tool extends, but does not add any other qualities to, a natural part of the body. Human tool use, on the other hand, is quite different since the tool has its “own logic, to which the natural capacity and make-up of the hand must adapt” (Haenen, 1996a, p. 33). A hammer, for instance, is grasped by the handle so that one can strike with its head. So, while the animal makes use of a ‘reservoir of manual operations’, the child ‘learns to make use of a reservoir of instrumental operations’, or, what might be called experience-based operations. The notion that tools reconstruct activities became the starting point in Gal’perin’s study of the development of tool-mediated activity.

Despite the differences in the tool use of humans and apes, Gal’perin extended the results from Köhler’s (1925/1973) research on problem solving by chimpanzees, and considered reasoning, rationality, and insight, to some extent, as objective characteristics of an action (Haenen, 1996a). Köhler had argued that problem solving in chimpanzees results from ‘insight’, that is, “the appearance of a solution complete with reference to the layout of the entire field” (ibid., p. 125). In his studies on problem solving, Köhler discerned three different phases. In the first phase the ape attempts to find a solution, during which it learns the relationships between the objects involved. Thereafter follows a period of survey where the situation is perceived in a new and different way. These two phases are a pre-solution period that leads to the third phase of sudden insight. In order for the insight to occur all parts of the problem space must be exposed. If any important parts are hidden, insight will not occur. Gal’perin transferred the observations made by Köhler when establishing his own research on the development of motor skills, which he investigated in the context of a task in which children retrieved toys from the bottom of a deep box with the help of a spade. He found that between the initial stage of manual operation and the final stage of tool-mediated operations there are intermediate stages during which the child starts to assess its movements, and isolates and employs the
successful ones. More precisely, the first thinking processes, or sensory-motor thinking, become available to the child through ongoing practical activity. Thus Gal’perin concluded that tool-mediated operations arise on the basis of manual operations. In Gal’perin’s view, the survey phase is extremely important for the improvement of motor skills, since “based on the experience acquired from the feedback from its actions, the subject builds up a representation of the problem space. This representation is used to execute and monitor further actions” (Haenen, 1996a, p. 126). In order to signify such representations and their function, Gal’perin introduced the term ‘orienting basis’, which later became central to his theory of systematic formation of mental actions, as described in the next section.

### 3.4.2 A framework for systematic formation

Gal’perin’s framework extends and further develops several of the concepts central to Vygotsky’s work, such as cultural tools, orienting activity, internalisation, and the zone of proximal development. In Vygotsky’s view, the main influence on mental activity comes from cultural-historical factors, but he also recognised the importance of biological factors (Vygotsky, 1934/1986). According to Haenen (1996a), Gal’perin instead considered mental activity as both “cultural-historical and material in origin, and with both origins present, there is a primacy of the material over the cultural-historical”. This idea is found in his earlier studies on tool-use in humans and apes, from which he concluded that thinking and tool-mediated activity arise on the basis of the manual operations of objects (cf. Section 3.4.1).

The relation between the material and the mental is an extension of Vygotsky’s principle of internalisation. In Gal’perin’s framework internalisation is, roughly speaking, a process in which concrete material activity transforms into mental, orienting activity (Gal’perin, 1977/1992). Vygotsky had recognised that culturally evolved cognitive tools acquired in the course of instruction, affect a child’s cognitive development, but he “did not specify how the particular content of instruction is related to development, and in particular, how specific qualities of the cognitive tools acquired by the child affect development” (Arievitch & Stetsenko, 2000, p. 73).

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41 This description bares some similarity to contemporary perception-action approaches. Yet, the views differ substantially in that Galperin theorises on the notion of insight, while the action-perception perspective does not, relating development to senso-motoric processes instead.

42 According to Galperin (in Haenen, 1996b, p. 59), Vygotsky “did not succeed in developing a method of systematic formation”. However, considering that Vygotsky died at the age of 38 (in tuberculosis), it might have been due to a lack of time, rather than ‘not succeeding’, to develop such a method. In his later work Vygotsky focused on word meaning, and the only empirical research there was time to complete within his framework was that carried out by Shif on concept development in children in the context of formal schooling (Minick, 1996). Galperin himself began to formulate the basic conditions, or prerequisites for the optimal formation of mental actions in the early 1950s, but the set of prerequisites was still incomplete thirty years later (Haenen, 1996a).
The other main source in Gal’perin’s theory is Leontiev’s theory of activity (Haenen, 1996a). While Vygotsky had focused on signs, Leontiev replaced signs with human activity as a mediator between subject and object. However, in Gal’perin’s view, Leontiev’s concept of activity was problematic as it was too all-embracing in its three-level analysis (Section 3.3.1), and not all parts of activity are psychology (Gal’perin, 1977/1992). Of the three levels of activity, Gal’perin only considered actions in his framework. In his opinion, actions may be material or mental. Material actions involve hands-on manipulation of external objects. For instance, when learning to count, children may use physical counters that are touched, moved around, or pointed at (cf. Section 2.2). Mental actions, on the other hand, are actions carried out in the head, where the external objects have been replaced with their images. These mental actions are part of what Gal’perin termed ‘orienting activity’, which refers to the mind’s role in activities (Haenen, 1996a):

orienting activity is mentally executed with the aid of thoughts and images in which real life situations are represented. On the basis of the representation of the problem space, a person can orient himself, foresee the effect of his own or somebody else’s actions, change his actions to fit the distinctive features if the situation, anticipate options in relation to his experience (his ‘knowledge of the world’), and achieve a successful execution of the action. Thus, a person can deal with a task or problem only if his actual action is preceded by orienting activity in the problem space as it is represented in the person’s mind. (p. 96-97)

Thus, the way things become represented in a person’s mind is crucial if the mental execution of an action is to facilitate subsequent performance. Gal’perin and his colleagues showed that orienting activities can be actively formed, with intended properties, by the use of material representations (further described in the next section). Such representations provide a means for controlling one’s own behaviour ‘from the outside’, as Vygotsky (1978) expressed it. The mental actions are the final products that emanate from “the transformation of and reflection on the execution of material actions” (Haenen, 1996a, p. 120). Initially, material actions may require several steps that later on, with increased skill in performance, become automatized (or ‘telescopied and automatic’) not requiring conscious reflection (cf. Section 2.4.2). In other words, mental actions are “internalized and abbreviated forms of external, material actions” (ibid.), and thereby material in their origin.

Briefly, Gal’perin’s theory, or research program, amounts to four basic assumptions, as described by Haenen (1996a):

1. Mental activity is a form of concrete, material, object-bound human activity. Gal’perin considered activities as personalised (and orienting, see point three), meaning that they are both subject-bound and object-bound: there is always a subject, an actor, in the activity, and the activity in turn is related to an object.
2. The structure and content of mental activity have to be studied in the course of internalisation. Mental activities emerge as a result of the transition from material to mental activity and it is precisely this
internalisation that needs to be studied in order to understand mental activities.

3. The final product emanating from internalisation is mental orienting activity\(^{43}\), which is used for directing and monitoring further actions in new problem situations.

4. Hence, orienting activity is the true subject matter of psychology. Gal'perin defined psychology rather narrowly, as being concerned with orienting activity, not with human, mental or cognitive activity in general.

According to these basic assumptions, as summarised by Haenen (1996a): “psychology is concerned with mental (ideal) orienting activity stemming from material (practical) activity and emerging as the final product in the course of internalization” (p. 112).

The systematic formation of mental activities, or more specifically, mental actions, is ensured by four significant prerequisites (Haenen, 1996a): the first one is the learning motive, i.e., the fact that children need to be genuinely motivated to learn. The second prerequisite is an orienting basis, i.e., a representation of the problem, which largely predetermines the quality of the action. Thirdly, actions may be classified according to four parameters of an action (a subset of prerequisites: level of appropriation, degree of generalisation, degree of abbreviation or completeness, and degree of mastery). These three prerequisites are integrated in the fourth which is the stepwise procedure\(^{44}\) that leads to full-fledged mental actions. Of special interest for the present purposes, is the orienting basis. The concept of orienting basis refers to “the whole set of orienting elements by which the learner is actually guided in the execution of an action” (Haenen, 1996a, p. 133). The orienting elements include external, material representations (such as instructions on how to solve a task), and the mental representations formed on the basis of the external ones. The external representations provide the learner with an understanding of a specific action, i.e., its goal, structure and means. Both the external and the mental then guide the learner’s execution of an action (further explained below).

In the 1960s through the 1980s, Gal'perin and his colleagues did a tremendous amount of work in the Soviet Union; studies were conducted on issues such as the formation of geometrical concepts, visual problem solving, the formation of attention skills in children with serious attention problems, and many more (Arievitch & Stetsenko, 2000; Gal'perin, 1977/1992; 1978/1992; Haenen, 1996a). Their work comprised studies in laboratories, schools and at enterprises, with participating subjects ranging from preschool children to industrial workers. The studies provided empirical support that different cultural tools affect learning and children’s cognitive development in different ways. Thereby they demonstrated the importance of

\(^{43}\) Galperin’s idea of orienting activity originated from Pavlov’s concept of ‘orienting reflex’, and its extension by Sokolov (Haenen, 1996a).

\(^{44}\) The stepwise procedure refers to ‘six stages of formation’ that results in ‘full-fledged mental actions’ (for further description, see Haenen, 1996a).
considering qualitative differences in tools. Furthermore, Gal'perin’s theory explains how the mental components can be formed actively by use of different kinds of instructions.

The next section provides an example of the transformation of external material actions into their mental form, in the context of school instructions. Of course, school instructions as such is not the main interest here. Instead, the example serves to point out that qualitative differences in tools affect the ensuing mental actions.

### 3.4.3 Instructions and cognitive development

In the context of school instructions, Gal'perin (1978/1992) analysed different kinds of learning and identified what is called traditional learning and learning based on insight, in his terms, first and second types of learning. Besides these, he discovered a third kind (third type) of learning. Each of these is closely related to a specific kind of teaching strategy, or instructions, which have elsewhere been named ‘traditional instruction’, ‘systemic-empirical instruction’, and ‘systemic-theoretical instruction’ (Arievitch & Stetsenko, 2000). The different kinds of learning and instruction are briefly described below, and exemplified by the formation of motor skills in writing letters and words.

Traditional instruction, which refers to the first type of learning, is predominant in most educational systems. This type of learning is characterised by more or less numerous trials and errors during which the learner gradually reaches a correct performance. In Gal’perin’s view, most (traditional) instructional methods "fail to provide the child with all the necessary tools and conditions for correct orientation in the task and therefore, for correct performance” (Arievitch & Stetsenko, 2000, p. 74). Similarly, traditional education has been criticised from situated/distributed perspectives for providing learners given problems with ready made solutions, which does not lead to much transfer of learning (Pea, 1993; Perkins, 1993; Resnick, 1991).

The second type of learning, related to systemic-empirical instruction, is achieved by providing the learner with a full set of conditions, that is, all the necessary conditions and criteria for effective performance as an interrelated meaningful system, or schema, from the very beginning (Arievitch & Stetsenko, 2000; Gal’perin, 1978/1992). Thus equipped, learning by trial and error becomes very rare, and development succeeds more rapidly than in traditional instruction. On the basis of Köhler’s and his own earlier research, Gal’perin argued that “insightful learning can occur if the subject (be it animal or a human being) has at his disposal a complete orienting basis consisting of all the elements of the problem space in question. With such an orienting basis the subject ‘comes to see’ the solution after pondering the problem” (Haenen, 1996a, p. 126; cf. Section 3.4.1). Despite

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45 It should be noted that Galperin’s ‘systematic formation’ is often mistakenly considered to be a pedagogical procedure, but it is not – it is a method through which internalisation can be actively guided (Arievitch, 2003).
the fact that this type of instruction advances learning much more rapidly than in traditional learning, there is a serious limitation to it; there is no knowledge transfer between domains, and therefore performance is still restricted to certain assignments in a particular domain, and each new case requires a new schema of a complete orienting basis of an action.

To overcome the limitations of the second type of learning, Gal’perin (1978/1992) embarked on a general method that would enable a learner to devise an orienting basis independently of any specific assignment. That led to the discovery of a third kind of learning, related to *systemic-theoretical instruction*. In this type of learning students are not provided with ‘finished knowledge’, rather they actively explore the studied subject, under a teacher’s guidance (Arievitch & Stetsenko, 2000; Gal’perin, 1978/1992). Students are provided with the means for theoretical generalisation that allow them to orient themselves in a systematic way in the subject under study. In this case knowledge transfer is achieved since students acquire a general method for constructing a concrete orientation basis to solve any problems in a given subject domain.

In a comparative study three groups of 6-year-old children were taught to write Russian letters, according to the different types of instructions described above (Arievitch & Stetsenko, 2000; Gal’perin, 1978/1992). In the first group, which used traditional instructions, letters were introduced one at a time. The children were shown and instructed on the reference points of letters, i.e., where a line begins, where it starts to curve, and so on. Learning proceeded very slowly, with many trials and errors. The performance was unstable and showed little transfer to other letters. In the second group, with systemic-empirical instructions, learning proceeded differently. All the reference points were pointed out to the children and they were given a ‘specimen’ of the final product (the pattern of a letter). In this group performance was much more stable and of higher quality, and learning proceeded more quickly and successfully. However, performance did not transfer, and for each new letter the reference points had to be pointed out again.

In the third group, with systemic-theoretical instructions, learning began by developing the child’s ability to distinguish necessary reference points. Using this general method the children could reproduce the model, or contour, of any letter on another page (by putting dots on the paper), and then duplicate the letter itself. Once the children learned how to distinguish the reference points (i.e., to construct the concrete orientation tool) of any letter, they could soon analyse and reproduce the letters visually, without putting any dots on the paper. The students easily replicated any letter of the Russian alphabet, and they also became able to reproduce any contour with high precision: letters from Latin, Arab, and Armenian alphabets, stenographic symbols, blueprints, and unfamiliar pictures. Learning from this method, then, by far exceeded the other kinds of instructions. In summary, what these experimental studies demonstrated, is the importance of providing the ‘right’ kinds of representations, that is, instructions that enable a learner to
advance in the least erroneous way possible. However, the consideration that learning should be error free has received much criticism, and Gal’perin has been criticised for considering learning as a ‘one-way transmission’ in which the child is a passive learner (for further discussion see Haenen, 1996a; van der Veer, 2000) (cf. Section 3.3.3 regarding the emphasis on active subjects in Soviet psychology).

As discussed in this section, Gal’perin viewed the quality of cognitive tools (in this case school instructions) as crucial in the formation of mental actions, and such tools are important for learning in the zone of proximal development (cf. Section 3.2.2). Commonly the notion of scaffolding is put in relation to the ‘zone’. The concept of scaffolding was introduced by Wood, Bruner and Ross (1976) to explain tutorial processes, that is, the way a more competent person (e.g., an adult) helps, or ‘scaffolds’, a less competent person (e.g., a child) to solve a problem. However, as pointed out by Arievitch and Stetsenko (2000), scaffolding “is only loosely related to the concept of cognitive tools and implies that the quantity or contingency (e.g., moving to less intervention after success and to more intervention after failure) rather than quality of content of the adult’s assistance has a decisive role in the child’s cognitive progress” (p. 72). It should be noted though, that Wood was among the first (in the ‘West’) to learn about Gal’perin’s work, and that the concept of scaffolding, as described by Wood et al., is in large part very similar to Gal’perin’s six stages of formation (Golder46, personal communication; cf. Haenen, 1996a).

Finally, the theory of systematic formation is not only a theoretical construct as such. On the contrary, this method is used, for instance, in Dutch elementary education, where one third of the elementary schools are using a method of handwriting, based on Gal’perin’s theoretical framework (Haenen, 2000). Somewhat ironically, however, the assumed benefits of Gal’perin’s theories (as well as the work of Vygotsky and Leontiev) have not been investigated in Russian education, and they are only scarcely used, if at all (Grigorenko, 2000).

46 Mario Golder had Leontiev as advisor during his Ph.D. studies, and he also worked closely with Galperin for some years.
4. Animal tool use

This chapter addresses the topic of animal tool use. Research has revealed differences as well as similarities in human and non-human primates on such issues as development, cognitive skills, tool behaviour, etc. According to Johnson (2001), who favours a distributed cognition view, the observable differences in behaviour of humans and other primates provide a possibility to generate hypotheses about humans and their cognitive skills, based on “the apparent structure and adaptive consequences of that behavior” (p. 174). An observable difference is, to use the words of Bateson (1972), “a difference that makes a difference” in the understanding of human behaviour. In this chapter I will discuss tool use in great apes and in social insects, to explore in what way they can contribute to understanding human tool use. Great apes are assumed to be the most advanced tool users among animals, having some cognitive capacities (although not at the level of human cognition). It is also a common assumption that insects are less complex than humans, exhibit a stimulus-response behaviour, and lack consciousness and other mental abilities. Therefore, at first glance it might seem strange to choose two such divergent species, but the issue here is not consciousness or which cognitive abilities they may or may not have. Instead, my interest concerns finding some generalisations of tool behaviour.

We may note that tool use was considered a uniquely human characteristic for a long time (cf. Section 1.1.1). However, regarding animal tool use, Gould and Gould (1999) note that

Indeed, some animals select absorbent bits of wood or other vegetation to soak up liquid food, then transport this ad hoc sponge home, a stratagem that increases their foraging efficiency by up to a factor of ten. Another species uses stones as tools to tamp down earth in an effort to conceal where it has been digging, then discards the stone, preventing it from serving as a signal that could attract parasites and predators. These two examples undercut the only-humans-use-tools argument with particular force because they involve mere insects-ants and wasps, respectively. (p. 83)

Tool behaviour (tool making and/or tool use) in animals has been reported in species ranging from insects, wood mice, corvids, capuchin monkeys, to the great apes (Beck, 1980, Bekoff et al., 2002; Fragaszy et al., 2004; Heindrich, 1999; Hunt & Gray, 2004; Stopka & Macdonald, 2003). Not everyone would agree that all reported cases in fact are tool behaviour, but that depends on how we define the term (further discussed in the next section).

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47 Following the common use of terms in literature on primatology, human and non-human primates here refer to humans and other primates, respectively. The term ‘great apes’ refers to chimpanzee (Pan troglodyte), bonobo (Pan paniscus), gorilla (Gorilla gorilla), and orangutan (Pongo pygmaeus). Even though humans also belong to the great apes, they are not included in the term ‘great apes’ for a convenient use of terms. For the phylogeny on primates, see Byrne (2000).
Section (4.1) focuses on tool use in great apes, and Section 4.2 describes tool behaviour in social insects, while Section 4.3 discusses some generalisations of tool behaviour.

4.1 Tool use in great apes

Much research on, e.g., development and learning emphasises the importance of social interaction between human infants and their caretakers. The social scaffolding provided by caretakers bootstraps the development of social skills and language (e.g., Hendriks-Jansen, 1996). But humans develop, not only social skills, but also skills in using various kinds of tools and artefacts. Infants and young children are exposed to a material culture, in which they manipulate material objects from an early age, and learn what objects are, and how they can be handled (Lockman, 2000). Skills for handling objects are also facilitated by social scaffolding, in which caretakers engage infants in triadic interactions and games including material objects. It has been argued that technology is "a defining feature of human culture [and the] most advanced forms of human technology are rooted in our capacities to fashion the materials of our environment into tools and employ them adaptively in diverse contexts" (Lockman, 2000, p. 137). These capacities may very well have their roots in early object manipulation. Great apes in the wild are not exposed to a material environment of the kind humans are exposed to, and therefore, they are not ‘materially enculturated’ as are humans. However, human-reared apes reach more advanced tool using levels than do their wild conspecifics, which might be taken as an indication of how much materiality and social scaffolding during early years affect later tool using skills.

Commonly, research in human and non-human primate cognition take on comparative approaches (which is also seen below). While such comparative approaches are common, they are all too often used as a means of arguing for human uniqueness, and take less interest in considering what can be learned about human (and ape) cognitive skills. The point here is not to argue for this or that marvellous skill in apes, or that humans are not that unique (each species is unique). However, Tomasello (2000) reasons that non-human primate cognition should play a more important role in cognitive science than it currently does since human cognition is similar to, and a specific instance of, primate cognition. Furthermore, considering that human and non-human primate cognition are identical in many of its structures, and the fact that great apes (who are closest to us) develop relatively slowly compared to the rapid pace of human development, primate tool use provides an opportunity to investigate the mechanisms underlying tool use (Greenfield, 1991; Tomasello, 1999; 2000; Tomasello & Call, 1997). Hence, rather than debating over what might be uniquely human, it is of more general interest to explore in what ways primatology may further our understanding of tool use.

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48 In primatology, enculturation is defined as “rearing nonhuman primates in human settings with the intent of transmitting cultural models and symbolic communication, so that they become active agents within a meaningful system of relations which they come to embody in their own actions and understanding” (Russon, 1999a, p. 182). Likewise, humans are reared in human settings, and are enculturated into a human cultural system.
understanding of human tool use. In the following I will make a brief tour into the long-standing controversies ensuing from research in primatology, and the focus on identifying the ‘hallmarks of humanity’. Primatology as such is not controversial, but the thought of comparing, to say nothing about the possibility of finding similarities in, human and great ape language skills, tool behaviour, or other cognitive abilities is an issue. Thereafter we will consider what is currently known about (primarily) tool behaviour in great apes.

Throughout time, the thought of comparing humans and other animals, and the possibility of any similarities between the two, has caused considerable unease. It has caused controversies across and within the fields of anthropology, ethology, and psychology. Scientists have disagreed on the ontogenetic and phylogenetic origins of tool use and “whether tool use is a uniquely human or primate capacity and the kinds of cognitive skills embodied in tool use” (Lockman, 2000). Furthermore, animal behaviour is commonly considered instinctive or ‘innate stimulus-driven actions’, while human behaviour is deemed learned through cognitive abilities (Fouts, 2003; Gibson, 1993; Savage-Rumbaugh et al., 1998). It has been said that “[w]hen we turn our attention to Mammalia...we find some startling us by forms and actions so much resembling our own, as to excite unpleasant comparisons” (Charles Hamilton Smith, 1842; quoted in Ritvo, 1991, p. 68). Understandably, comparisons were ‘unpleasant’ – after all, man was considered to possess capacities no other species had, intelligent capacities expressed in the ability to make and use tools. These abilities, then, were deemed the defining characteristics of man. Bergson, for instance, stated that

If we could rid ourselves of all pride, if, to define our species, we kept strictly to what the historic and prehistoric periods show us to be the constant characteristic of man and of intelligence, we should say not Homo Sapiens but Homo Faber. In short, intelligence, considered in what seems to be its original features, is the faculty of manufacturing artificial objects, especially tools for making tools, and of indefinitely varying the manufacture. (Bergson, 1911/1938, in Cole, 1996, p. 139)

However, tool use among chimpanzees was reported as early as 1843 by Savage and Wyman (1843), who had observed chimpanzees using stones for cracking hard nuts (a fact long known by peoples of West Africa; Fouts, 2003). Even Darwin was aware of tool use among chimpanzees and orangutans (Gould & Gould, 1999). However, not even the appearance of Darwin’s theory of evolution changed the reluctance to admit similarities between man and other primates. Instead, disciplines like comparative psychology, and cognitive science for that matter, have maintained the human animal dichotomisation, and focused on intellectual and emotional qualities assumed to be uniquely human (Ritvo, 1991)49. Even as reports on

49 As pointed out by Ritvo (1991), this dichotomisation, or “intellectual construction”, also has determined the course of education: “Throughout our educational system students are taught that it is unscientific to ask what an animal thinks or feels... [and] field naturalists are reluctant to report or analyze observations of animal behavior that suggest conscious awareness...lest they be judged uncritical, or even ostracized from the scientific community”
animal tool use, especially among chimpanzees, changed the belief of man as the sole tool maker, the search for the distinction between man and animal continues. Ritvo (1991), for instance, has pointed out that such a distinction, or dichotomisation, has been present at least since the time of Aristotle, and therefore we barely notice it. The dichotomisation has also been sustained by the fact that, as Gardner and Gardner (1991) say, absence of evidence (for some capacity in animals) has been considered as evidence of absence (for that capacity) - a view that fits well with the theme of a *scala naturae*:

> Since Aristotle, natural philosophers have proposed criteria for ordering the animal kingdom along a scale that would place humanity firmly and scientifically somewhere above the brutes, yet lower than the angels. Like college instructors looking for a gap in the distribution of examination scores that justifies awarding A's to one group of students and B's or less to the rest, natural philosophers look for a gap that separates human from brute. (ibid., p. 558)

But, as Gardner and Gardner (ibid.) further point out, time and again these gaps have “turned out to be temporary gaps in human knowledge”. Along with the advancing knowledge, especially concerning chimpanzees, the defining characteristic trait of humans has changed. Subsequently, Franklin’s notion of ‘man the tool-using animal’ has been modified to ‘man the skilful maker of tools’, to ‘man the habitual tool maker’, and then again to ‘man the user of language’ (Piperno, 1993; Strum, 2001). As noted by Strum (2001, p. 74), “[e]ven this last definition is under attack now that a variety of apes can converse with their human observers in American Sign Language, or by symbols on a computer or board”.

The debate continues and people who base their thinking on the uniqueness of the human species often resist even the very idea that a dichotomisation is controversial (Ritvo, 1991). To take but one example, Trefil (1997) argues that apes and humans are differentiated because only humans make tools and possess language (language is discussed further below)\(^50\). In asserting his argument about tool making, Trefil briefly mentions some cases of tool use and tool making in animals (e.g., chimpanzees modifying and using a stick as a fishing tool), which he says “have caused some commentators to announce gleefully that differences between humans and other animals are ‘only a matter of degree’” (p. 37) – an argument he finds “distinctly underwhelming”. Trefil further suggests that, in logical terms, the argument proceeds as follows (p. 38):

1. A stick is a tool.
2. A 747 (or a supercomputer or the Empire State Building) is a tool.

(p. 69, quoting Donald Griffin). An example is Strum’s (2001) baboon research which was met with great disbelief and accusations by the scientific community when it revealed the social likeness of baboons to humans, and contradicted long held assumptions of male dominance among baboons.

\(^{50}\) Other arguments concern for instance Theory of Mind, which is ruled out by Trefil as far as chimpanzees are concerned. However, that issue is outside the scope of this thesis (for a discussion in the issue, see, e.g., Heyes, 1998; Povinelli, 1996; Premack & Woodruff, 1978).
3. Therefore, the difference between a stick and a 747 is only a matter of degree.

In Trefil’s view, such reasoning hides the important fact that “there is a point at which differences in degree become differences in kind”. A raindrop, for instance, is “fundamentally different from a raging flood, even though both are made from water”. Subsequently, he argues that “anyone who calls the difference between the ability to build a 747 (or even the ability to build a fire) and the ability to use a stick ‘just a matter of degree’ is being wilfully obtuse” (p. 38, emphasis added). However, this line of argument is somewhat like comparing apples and oranges, since Trefil’s ‘logical’ reasoning transforms the argument of difference in degree (between different kinds of tools) to a concern about the ability to make and use tools. Obviously, it makes the case when comparing complex tool making (such as building a 747) and the seemingly simple use of a stick (‘ant-dipping’ with a stick is certainly not a simple matter though, see Gardner & Gardner, 1991). In conclusion, Trefil argues that while humans are able to both make and use tools, apes only can use tools, even as he recognises that chimpanzees modify sticks (which qualifies as tool making, further discussed below). Subsequently, according to Trefil, tool making is “one trait that distinguishes humans from even our nearest primate neighbors” 51 (p. 38) (for other such ‘logical’ arguments, see, e.g., de Waal, 2001).

Despite some scientists’ reluctance to admit tool behaviour in apes, numerous such observations have been reported, and elementary technology is common in ape material culture (McGrew, 2004). Elementary technology refers to “the knowledgeable use of one or more physical objects as a means to achieve an end” (ibid., p. 103). Matsuzawa (1996, in Hayashi et al., 2005) has further categorised primate tool use as “level 1” and “level 2” tool use. Level 1 tool use involves a single relationship between detached objects, where the tool is related to a target, for instance, using a twig for termite fishing. Level 2 tool use, instead, involves two kinds of relationships among detached objects, as in nut cracking; a nut is placed on an anvil stone, and hit by a hammer stone. The next few paragraphs provide some examples of tool behaviour observed in captive, enculturated, and wild great apes, including both level 1 and level 2 tool use.

**Chimpanzee** tool behaviour includes, for instance, modification of sticks and twigs for probing termite holes (ant-dipping), sticks for scratching, and sponges (leaves) for soaking up fluids (Beck, 1980; Goodall, 1986; McGrew, 1992). Chimpanzees are also known for their use of hammers and anvils for nut cracking. An anvil can be a root, tree trunk, or a stone, and the hammer can be wooden or a stone. According to McGrew (2004), nut cracking is a skilled motor activity in which appropriate force must be used so the nut will not be smashed, or resist the blow, and there is also a correlation between the hardness of the nuts and the hammer tools used for cracking them. It

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51 Chimpanzees are our closest living relatives, and chimpanzees and humans have an affinity of up to 99% in DNA, which would classify any other pair of species as siblings (Fouts, 2003; Strum, 2001).
has also been found that stone tools are rare in some areas, and are therefore carried between different worksites. So far, nut cracking is the only known case where chimpanzees use metatools, that is, “a tool that serves as tool for another tool” (Matsuzawa & Yamakoshi, 1996, p. 215), which is the most complicated form of chimpanzee tool use. By placing an additional rock as a wedge under the anvil rock, the anvil is levelled and stabilised (Boesch, 1991; 1993; Matsuzawa & Yamakoshi, 1996). This involves three relationships among detached objects (a wedge rock positioned under the anvil rock, target nut placed on the anvil rock, and nut hit by a hammer rock). Nut cracking is not, however, a universal chimpanzee behaviour, but rather a case of cultural variation. The practice of nut cracking between different groups of chimpanzees varies in that they use different tools (branches or stones) for exactly the same thing (cracking nuts), and some groups do not crack nuts at all even though they live in similar habitats as nut cracking groups, with access to a number of nut species and different kinds of tools (Berthelet & Chavaillon, 1993; Ingmanson, 1996; McGrew, 2004).

Tool use skills (such as nut cracking and termite fishing) are gradually acquired during the early years, and become fully developed at the age of 8-14 years (Biro et al., 2003; Lonsdorf, 2006). Young chimpanzees stay close to their mothers until the age of 4-5 years and they are allowed to observe, explore and manipulate tools, nuts, kernels, termites, etc. However, there is no active teaching of tool using skills, instead these skills are learned through close observation of their mothers (and other adults), a process called ‘education by master-apprenticeship’ (Matzuzawa et al., 2001, in Biro et al., 2003) (Figure 10). A critical age for acquiring the skills is 3-5 years of age, and chimpanzees who have not learned them by the end of this period will not do so. Active teaching has only been observed on two occasions, and for the time being, it seems that active teaching is restricted to enculturated apes, or apes in captivity (Biro et al., 2003). Skill acquisition has been observed to take place at an earlier age in captive chimpanzees than that of chimpanzees in the wild. It has been hypothesised that the learning is affected by the captive environment, which provides more opportunities for object manipulation and observation than in the wild (Lonsdorf, 2006).

Figure 10. An adult female cracking nuts, with two juveniles closely observing her actions (picture used with permission by Biro et al., 2003).
Chimpanzees also use tools socially. For instance, branches and stones are used for hitting or throwing, and branch-dragging is common in charging displays, and in courtship males shake branches to attract a female’s attention. Amorous males in one group of chimpanzees (at Mahale) engage in leaf-clipping (dead leaves are clipped in the lips which makes a characteristic tearing sound), but elsewhere in Africa leaf-clipping may signal tension or play (van Schaik, 2004). According to van Schaik (2004), the use of elementary technology varies from what is simply functional (e.g., nut-cracking,) to the possibly symbolic (e.g., leaf-clipping). If indeed leaf-clipping is symbolic use of objects, then it is an act with bearing on Vygotsky’s notion of signification (discussed in Section 3.2.1). In Vygotsky’s view, what distinguishes man from animal is signification, that is, creation and use of artificial signs. A sign is the mediator that allows humans to break away from biological development and create new forms of culturally-based psychological processes. The sign, or extrinsic stimuli, is also what allow humans to ‘control their behavior from the outside’. Whether or not leaf-clipping in fact is a sign that allows apes to break away from biological development and create a new form of a culturally-based psychological process, is for future research to discover. If it is a symbolic behaviour, an implication is that signification might be a matter of difference in degree rather than a distinguishing factor between man and animal. For now, leaf-clipping seems at least to be a means of controlling the behaviour of others’, and a culturally-based behaviour, with different meanings in different groups of chimpanzees. We might also note that research on apes in captivity clearly indicates that they have the capacity for learning things that have not been observed in the wild, and they have the ability to create artificial signs, such as novel signs for new things (Fouts, 2003).

Orangutans are also known for their skilled tool use, which, however, reveals a paradox. In captivity they are perhaps the most advanced tool users among the great apes, if the need and opportunity arises. In the wild, however, they are renowned for their lack of tool use and their marked asociality (Russon, 1999b). Captive and rehabilitant orangutans are known for flexible tool behaviour, and they have demonstrated (imitated) abilities such as sharpening an axe blade, or sweeping a path with a broom. One well-known enculturated orangutan, Abang, learned to use a hammer to strike a flint core to create a flake, and then used the flake to cut a cord in order to open a box (Wright, 1972, in Gardner & Gardner, 1991; Russon, 1999b). Evidence of tool use among orangutans in the wild has been limited, but reported observations include, for instance, sticks for scratching, branches used as missiles, and leafy branches used as ‘umbrellas’. Recently, however, more flexible tool making and tool use have also been observed in wild orangutans (Fox, et al., 1999; van Schaik, 2004). They make and use tool kits, which include different manufactured tools, each used in a specific context. Tools are manufactured, for instance, for probing and extracting honey and insects. They are also modified for extraction of seeds in the cemengang fruit (van Schaik, 2004). When the seeds are ripe the fruit begins to crack open, but the seeds are embedded in irritating, stinging hairs. The orangutans systematically insert a tool into the cracks of the fruit, and
scrape off the stinging hairs. The seeds are then pushed towards the open top of the fruit and scooped out with a finger or with the tool, or dropped straight into the mouth. There also seems to be a functional fit between tool dimensions and tool efficiency: fruit tools, for instance, are consistently shorter and thinner than tree-hole tools. As the season progresses, the cracks of the cemengang fruit widens, and thicker (but not longer) tools are used. Initially, fruit tools tend to be too long, but after they have been used a bit they are trimmed by biting off a piece, and once the tool is of the right length it can be used for several fruits and even carried to the next tree. It also seems there is planning involved; while orangutans are on their way to a cemengang tree, tools are often made during the approach. Sometimes, however, a fruit is stashed in a tree fork to which they return later. Van Schaik (2004) believes that they use one tool for fruits with cracks of a certain size, and store fruits with cracks of other sizes and return when they have a tool of the right thickness. Even though these different tools are, as van Schaik (ibid.) puts it, ‘ridiculously simple’ – just short, straight sticks made from branches snatched off the nearest tree – it takes several years to develop the proper tool making and tool using skills.

In captive gorillas tool use is quite common, including, for instance, modification of objects for use as dipping tools, missile throwing, sponging, probing, using a container for water, using a stick to hold food (as with a fork), and hammering (Taylor Parker et al., 1999). Gorillas differ from, e.g., chimpanzees, by not using tools in foraging, even though they exhibit a great variety of techniques in their rather complicated food processing behaviour (Boysen et al., 1999; Byrne, 1996; 1999). Gorillas in the wild had not been observed using tools, and have therefore often been considered less intelligent (than chimpanzees), since intelligence is considered to be related to, e.g., skills or techniques in tool behaviour (Byrne, 1999). Only very recently did the first report of tool use in wild gorillas appear. Breuer et al. (2005) observed two instances of western gorillas using branches for postural support in a swampy area. In the first case, a gorilla crossed a pool of water, using a thick branch for prodding the water in front of her, and then used the branch as a walking stick for support. In the second observation, a gorilla detached a thick branch, and pushed it forcefully into the ground. She subsequently held onto the branch for support with one hand, while dredging for food with the other. According to Breuer et al. (2005), it also seems that gorillas use branches as bridges in the swampy areas where the observations were made. The extent of these, and possibly other types of tool use, is for future research to reveal.

Bonobos in captivity have been observed using, for instance, cups, sponges, probes, and ladders (Ingmanson, 1996). Similar to the orangutan Abang, Kanzi, a well-known captive bonobo, has not only learned to produce usable stone flakes, but also to use the flake for cutting a cord in order to open a box with a food reward (Schick et al., 1999; Toth et al., 1993). Furthermore, Kanzi has learned to use a symbolic system of lexigrams for communication (Savage-Rumbaugh et al., 1998). As with the orangutans and gorillas, evidence of tool behaviour in wild bonobos has, until quite recently, been
rare. Previous observations include, e.g., use of ‘rain hats’ made of small leafy branches, and use of vegetation as a means of indicating travel direction (Ingmanson, 1996; Savage-Rumbaugh et al., 1996). Typically bonobos in the wild travel with a group that has been split into subgroups, often following the same path from one feeding site to another (such subgrouping patterns have not been reported for other apes) (Savage-Rumbaugh et al., 1996). Two ways of communicating group movements are ‘branch-dragging’ and the use of flattened or broken vegetation. Through such communication the subgroups know which direction the group ahead is taking, even when they are not visible or they are silent. ‘Branch dragging’ is used to initiate movement (in a specific direction), indicate direction, signal directional changes, and for keeping the group together. Branches (or rather, small trees) are carefully selected, foremost by adult males, and dragged through the bushes (Ingmanson, 1996). This dragging creates a lot of noise, which is believed to have an important function since visibility is poor in the dense woods of the bonobos’ habitat. Similar findings have been reported by Savage-Rumbaugh et al. (1996), even though they are more cautious in their conclusions as to whether or not bonobos intentionally use vegetation for the communication of information. On the other hand, it is clearly indicated that bonobos use flattened and broken vegetation to “signal something that is both specific and necessary”. Savage-Rumbaugh et al. (1996) observed that bonobos use vegetation in several different ways. For instance, they break both small and large branches and lay them on the trail, pull off branches and stick them into the ground in an upright position, and deliberately flatten short plants in a way that does not coincide with their trail length. These uses of vegetation served to confirm travel direction and indicated the right direction at crossing trails, the presence of water, when there were objects on the trail, etc. On the whole, branches and other vegetation were not randomly distributed and occurred most often when the trail was not clear and easy to follow. Further recently reported examples of tool use in wild bonobos include, e.g., the use of leaf clipping by mouth (to invite social play) or hand (to attract the attention of a mating partner), use of leaf sponges, and leafy twigs employed as fly whisks (Hohmann & Fruth, 2003).

The last few paragraphs have established that tool behaviour is present among all the great apes. As previously mentioned, a common question regarding tool behaviour concerns to what extent ape tool behaviour is similar to (or differs from) human tool behaviour. In Section 2.4.3 I described Baber’s tool use theory, which also discusses the difference between human and ape tool use. According to Baber, although there are some similarities in humans and apes, the difference is the human ability to ascribe meaning to objects, and to collect objects for future use. However, considering some of the cases of tool use described in the previous few paragraphs, the difference may not be that clear cut. For instance, the stones used by chimpanzees for nut cracking are not just any stones haphazardly lying around. In some areas, stones of the right size and quality are rare, thus those that have been found are kept and transported from one site to another. There might be a fine line between ‘collecting’ and ‘carrying along’, but it seems, even though
it is an anthropomorphic way to phrase it, that the stones are ascribed with 
meaning and are collected for future use. The same argument should apply 
to orangutans who make tools and collect tool kits on their way to a certain 
tree. A quite contrasting explanation is provided, for instance, by the 
functional tone concept (cf. Section 3.1.1) according to which it can be 
argued that apes do ascribe meaning to objects. As previously discussed, an 
object acquires a functional tone when an animal enters into a relationship 
with it. Thus, a stone can acquire a ‘pounding-quality’, a stick can acquire a 
‘seed extraction-quality’, etc. It is notable that Baber applies a human tool 
use perspective to animal behaviour, but from the apes’ perspective, it might 
be an unnecessary effort to collect and keep tools for future use when most 
of the tools are commonly available in their environment (the exception being 
the stone tools mentioned, the ones not commonly available). It has been 
said that wild “chimpanzees no more invent unnecessary tools than Efe 
pygmies in tropical rainforests invent ice-picks” (McGrew, 2004, p. 128). To 
this we might also add that probably they no more collect unnecessary tools 
than Efe pygmies would collect ice-picks.

Before drawing any conclusions about tool behaviour, we will attend to a 
brief discussion on the issues of language and gesture. Although they are 
not primary issues of interest in this thesis, they are of a certain relevance in 
the context of tool use and social interactions, which is discussed further 
below. As in the case of tool using skills, ape language research has caused 
much debate. Opinions, roughly speaking, range from ‘apes having no such 
skills at all’ to ‘apes having impressive language skills with some degree of 
complexity, albeit not at the level of humans’. However, we will not dwell on 
what degree of linguistic complexity apes may acquire. Instead, we will 
briefly examine the relation between gesture, language, tool use, and 
interaction. On the issue of language and gestural ability, it has been 
questioned whether or not apes have the capacity to acquire at least 
primitive linguistic and gestural skills. Chomsky (1968, quoted in Canfield, 
1995, p. 195) for instance, argued: “…[a]ll normal humans acquire language, 
whereas acquisition of even its barest rudiments is quite beyond the 
capabilities of an otherwise intelligent ape”, and more recently Donald (1991, 
p. 126) has claimed: “[d]espite their cognitive achievements, apes in the wild 
do not possess even a rudimentary system of voluntary gestures or signs”. It 
all depends of course on how we perceive the terms language and gesture 
(see, e.g., Goldin-Meadow, 2003; Shanker & King, 2002). Addressing the 
question of the rudiments of language, Canfield (1995) suggests language is 
rooted in “certain presymbolic interaction patterns, ones that come to light 
also in studies of ape language” (p. 197). These interaction patterns, termed 
proto language-games, are acquired during the child’s natural interactions 
with a caretaker. The proto language-game is a stage that precedes even the 
simplest natural gestures, as in the mutual recognition between child and 
mother and their subsequent reciprocal engagement. Some of the gestures in 
proto language-games become stylised and form natural gestures, in 
Canfield’s words “such an action is in some way modified, emphasized, or 
added to, in a way that brings it to the other’s attention, and thus it becomes 
a natural gesture” (p. 199). Canfield takes grooming between a baby
chimpanzee and its mother, a routine event among chimpanzees, as an example. When the mother wants to groom the baby chimpanzee’s sides and armpits, she takes his arm and pulls it upwards. Later, when the baby chimpanzee comes to his mother, he adopts the same posture in order to be groomed. The same use of gestures is also seen in human infants; initially, they raise their arms as a passive response to being picked up, and later they actively raise their arms as a request to be picked up. Canfield claims “once the simple language-game comes into being...it can serve as the underlying interaction pattern out of which may emerge new, more complex language-games” (p. 202). Thus, according to Canfield, the rudiments of language and gesture, are rooted in early interaction patterns, which are seen not only in human children, but also in apes. More recent Ape language research has also shown that apes can acquire at least rudimentary linguistic skills (see, e.g., Savage-Rumbaugh et al., 1998; Shanker & King, 2002).

Ape language research (verbal, signs, etc.) dates back to at least 1900, when an attempt was made to teach a chimpanzee to say some words (Lyn Miles, 1999). At the time it was not known that apes lack vocal cords, and, of course, the attempt failed. Later research has instead employed other means for communication, such as American Sign Language (ASL) and the use of lexigrams. Today, perhaps the most well-known language-trained apes are Washoe (chimpanzee), Chantek (orangutan), Koko (gorilla), and Kanzi (bonobo, or pygmy chimpanzee) (Bonvillian & Patterson, 1999; Fouts, 2003; Lyn Miles, 1999; Savage-Rumbaugh, et al., 1998). Washoe, Chantek, and Koko have been taught ASL. Washoe was the first chimpanzee to acquire human language, and later on her adopted son Loulis became the first non-human to acquire human language from other non-humans (Fouts, 2003). He learned from observing others, and Washoe also taught Loulis by molding his hand into signs (Fouts, 2003; Koko also molds the hands and arms of her dolls into signs, see Koko.org). Kanzi instead communicates through the use of lexigrams, i.e., symbols representing words. Initially Kanzi was not formally trained in language, instead he acquired his communicative ability by being present at the sessions in which his mother was trained to use lexigrams (Savage-Rumbaugh et al., 1998).

Another example of lexigram use is Sherman and Austin, two chimpanzees (Savage-Rumbaugh et al., 1998). The goal of teaching them to use lexigrams was not to see whether they could achieve true human language, but to improve their communicative competence. As their skills increased the two chimpanzees’ interactions became enhanced and extended, and they were able to develop new types of communicational exchanges. In an experiment involving communication and tool use,
appropriate tool (e.g., a key or a wrench) and pass this through a small hole to Sherman. Sherman would then open the right box and pass the food through to Austin (eating a small portion of it along the way). (p. 121)

The experimental task was performed easily by the chimpanzees, but what is more interesting is the behaviours that resulted from their inter-individual interactions. For instance, symbols were amplified with gestures, and there was a spontaneous correction of errors. Thus, Sherman and Austin were able to use the lexigrams to coordinate their interactions, as in the food retrieval task described above. According to Shanker and King (2002), it can be said that Sherman and Austin reached a point where they not only understood the meaning of the lexigrams they used, but also each others’ use of them.

These language trained apes are all (to some degree) enculturated, that is, reared in human-like cultural settings, which could explain their communicative skills. Raising chimpanzees in a human cultural environment affects their ontogeny in such a way that their behaviour can be described as more human-like than like the behaviour of their conspecifics in their natural environment. In Tomasello et al.’s (1993) view, enculturation not only leads to the development of imitative skills, but also more fundamental social-cognitive abilities. By interacting with humans, a chimpanzee adapts to interactions around objects, and directs its attention to them in a way that does not occur in its natural environment. For instance, Tomasello et al. (1993) studied the effect of the cultural environment on imitative learning of novel actions on objects (tools and other hardware objects). The subjects in their study were children, mother-reared chimpanzees, and enculturated chimpanzees. The subjects were to imitate actions on objects performed by the experimenter. In most of the trials, imitation was to immediately follow demonstration, and they revealed that both children and enculturated chimpanzees outperformed mother-reared chimpanzees. However, Russon (1999a) argues that the power of human enculturation may be exaggerated, as free-living apes show the same cognitive levels as do enculturated apes. Furthermore, while the enculturated apes’ achievements are scaffolded, the free-living apes’ achievements are not. Nevertheless, it has been argued that the significance of the power of (human) culture is demonstrated, not only in chimpanzees’ imitative skills, but also in the language skills acquired (cf. above). Tomasello et al. (1993) and Savage-Rumbaugh et al. (1998) further maintain that the power of enculturation also indicates the importance of the socio-cultural environment for human children and their development in learning and social-cognitive skills (this opinion is very much in line with Vygotsky’s view on the importance of the socio-cultural environment for development, cf. Section 3.2).

Captive chimpanzees and orangutans are known to be ‘notorious imitators’ of human tool use (Beck 1980), but whether or not apes have ‘true imitating skills’ is a question under debate (Russon, 1999b; Tomasello, 1996; Whiten & Custance, 1996). However, the ability of apes to use sign language does tell us that apes are very good at (at least) some level of imitation, “in fact, that ability is at the heart of their acquisition of sign language” (Donald, 1991, p. 125).
Human and ape cognition share some identical structures, and up until about the age of three years there are similarities in their development (Greenfield, 1991; Tomasello, 2000). Enculturated ape communication is commonly regarded to reach the level of a child of 2.5–3 years of age, with similar syntax and content. Furthermore, both children and apes participate in object manipulation; they bang objects together, place them into containers, and throw them. Tool use, however, requires certain tool using capacities, and while apes do have tool using and constructional schemes they are limited compared to humans (Gibson, 1993). As children begin to combine schemes into ever longer tool-using sequences (cf. Section 2.4.2), their object manipulation becomes more complex. Such sequences require that several spatial relationships or objects are kept in mind simultaneously. A recent study of chimpanzee stone tool use by Hayashi et al. (2005), reveals some problems associated with keeping longer sequences in mind. In their study, naive captive chimpanzees were introduced to stone anvils and hammers, and a human tester demonstrated nut cracking behaviour. While two of the chimpanzees succeeded rather quickly in cracking nuts, the third one failed, even after extensive training. Hayashi et al. (2005) discuss three main difficulties that may account for the failure. Firstly, striking (or pounding), especially with an object, is not a common action among most primates, and it requires adjusting skills with regard to angle and force of the strike. A second difficulty concerns the sequence of actions. While the goal of nut cracking is to reach the edible kernel, the initial target (the nut) is put aside as attention shifts to the tools. Hayashi et al. (ibid.) describe it as a “detour” to reaching the goal of eating the nut. A third difficulty involves the combination of the three objects anvil stone, target nut, and hammer stone, which involves two kinds of relationships among detached objects, that is, level 2 tool use. As argued by Hayashi et al. (ibid.), tool using skills require that all three difficulties are overcome. It might be supposed that mastering these difficulties is part of the constructional tool using schemes children learn to combine into ever longer tool using sequences. However, these schemes develop rather late in children, and they are absent in apes. It has also been argued that humans reach a more complex level of cognition due to a larger capacity for information, which perhaps enables keeping longer tool using sequences in mind. It has also been suggested that behind complex human behaviours lie the mutual interdependency and reinforcement of tool use, social behaviour, language and mathematical thought (Gibson, 1993; cf. Greenfield, 1991, see also Taylor Parker & McKinney, 1999).

In the present context, what is interesting about the behaviours mentioned so far (tool use, language, interactional patterns, gesture), is their interrelatedness, which has implications for understanding tool use and technology (Capra, 2002; Fouts, 2003). It has been argued that interactional patterns precede gestures, and that language originated in gesture (Canfield (1995; cf. Rizzolatti & Arbib, 1998). As described by Fouts (2003), both sign and spoken language are forms of gesture; gesture of the hands and gesture of the tongue. It has been suggested that early hominids developed skills for precise hand movements both for gestures and tool making, and that the
evolution of gesture eventually triggered tongue movement (precise speech and hand movements are controlled by the same motor areas in the brain\textsuperscript{53}). In addition it has been argued that these insights have implications for the understanding of technology:

If language originated in gesture, and if gesture and toolmaking (the simplest form of technology) evolved together, this would imply that technology is an essential part of human nature, inseparable from the evolution of language and consciousness. It would mean that, from the very dawn of our species, human nature and technology have been inseparably linked. (Capra, 2002, p. 58)

However, as argued by Morris (2005), the ‘simplest form of technology’, or tool use, is not always necessarily the use of material objects. In collective behaviour, primates sometimes help one another, or use the body of another primate, a phenomenon he calls “tooling up others” (p. 64). Morris suggests that perhaps inanimate objects such as sticks do not “tool up” like a primate body does because they are not really animate helping hands. For primates working together, what we call a “tool” is “an extra hand that lends a hand to a primate’s hand” (p. 65). The case of Sherman and Austin cooperating to retrieve food from locked boxes exemplifies how each one “tools up” the other. It could be argued that they were forced to cooperate since only one knew which tool was needed for which box, and the other alone had access to the tools. However, without ‘lending an extra hand’ to each other, they would not have solved the task. Hayashi et al. (2005) describe further cases of “tooling up others”. One instance involves some apes that tried to make a tester solve a problem for them, and another a chimpanzee who took the tester’s hand and moved it close to a stone or a nut, or hit a nut with the hand. These behaviours are also termed “social tool use”. Human use of inanimate tools, Morris argues, is “our human way of equipping ourselves for ‘loner-being’” (p. 65) (cf. Section 2.3 and the blind man using a stick). Morris, who criticises the comparative studies of human and animal cognition that focus on single humans and animals (cf. 3.1.4), argues that “if we abandon our tool-centric and lone-body prejudiced way of looking at things, we might find that the original of the tool is not the stick, but the other’s hand” (p. 65).

To summarise this section, great apes make use of a variety of tools, including conspecifics when ‘tooling up others’. Furthermore, there are similarities as well as differences between humans and the great apes, which are often described in terms of the level of skill reached by each. However, as Bekoff (2002) argues,

...little is to be gained from comparing, for example, the cognitive or emotional ‘level’ of a chimpanzee to that of a human child, for each individual does what he or she needs to do to adapt to the demands in his or her own world. Some investigators claim that an adult chimpanzee functions at about the level of a two-and-a-half-year-old human child, but surely a young child could never survive in the chimpanzee’s world. (p. 13)

\textsuperscript{53} Discovered by neurologist Doreen Kimura in the 1970s (Fouts, 2003).
Of greater interest than comparing some ‘level’ of behaviour, is what can be learned from primatology. Ape language research has shown, according to Savage-Rumbaugh et al. (1998), that “we can learn a great deal about the phenomenon of language itself as we attempt to produce it in apes...[a]pe-language research has taught us a great deal about dimensions of language that likely would never have been teased out in the study of normal children” (p. 120). Similarly, we can learn about human tool behaviour from research in apes’ (and other non-human primates’) tool behaviour. To dismiss tool making and tool use in animals (e.g., on the basis of some ‘logical’ reasoning where ‘difference in degree becomes difference in kind’) would be to (dis)miss opportunities of learning more about human tool use.

In Section 4.3 some of the issues discussed in this section will be revisited. First, however, I will explore tool use in social insects.

### 4.2 Social insect behaviour

This section describes social insect behaviour, with a focus on the concept of stigmergy. Stigmergy was introduced in the late 1950s by Grassé, who studied the behaviour of social insects. The concept itself refers to “a class of mechanisms that mediate animal-animal interactions”. Stigmergy is a coordination mechanism that explains how social animals achieve coordinated behaviour at the societal level (Theraulaz & Bonabeau, 1999; the following brief historical overview of stigmergy is based on their article). Stigmergy provided an alternative theory for understanding the coordination paradox, that is, the connection between the individual and the societal level. When observing the behaviour of a group of social insects, they seem to be cooperating in an organised, coordinated way, but looking at each individual reveals that they seem to be working as if they were alone and not involved in any collective behaviour. In early attempts to explain collective behaviour of social insects, an organicist metaphor for this phenomenon was used, since there appeared to be what could be described as a coordinating agent “virtually” present at the centre of the colony. As described by Theraulaz and Bonabeau, at this early stage a set of common characteristics for social organisms and living systems was pointed out by Spencer. These common characteristics included, for instance, progressive and joint differentiation of structures and functions, mutual shaping of the parts of which they are made, and division of labour. The first systemic approach of studying social phenomena was introduced by Wheeler at the beginning of the 20th century, who wrote:

> An organism is a complex, definitely coordinated and therefore individualized system of activities, which are primarily directed to obtaining and assimilating substances from an environment, to producing other systems, known as offspring, and to protecting the system itself and usually also its offspring from dangers emanating from the environment. (Theraulaz & Bonabeau, 1999, p. 98)

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54 Part of this section appeared in similar form in Susi & Ziemke (2001).
According to Theraulaz and Bonabeau, Wheeler suggested that insect colonies might have functioning constraints, enabling societies to behave as if they were single and unique organisms. Laws similar to those that govern living organisms must therefore control the organisation of a society. This view was supposed to explain the achievement of coordination. At the time, the laws themselves could not, however, be explained since no sufficient scientific tools and concepts were available. The organicist metaphor had no explanatory value and could only serve as a means for finding similarities between global societal properties and single organisms. Other scientists, denying the organicist metaphor, concentrated instead on the study of individual behaviour. Among them was Rabaud, who was very suspicious of holistic explanations. However, the focus on individual behaviour had a tendency to oversimplify the nature of social phenomena, as seen in Rabaud’s claim that the only cause of behaviour lies within an individual, and “if cooperation occurs it is only by chance and as a result of unexpected incidents” (ibid., p. 99). In Rabaud’s view each individual is doing its own work, without paying any attention to the work of others, and therefore they have no noticeable influence on each other. He considered collective work as merely a “juxtaposition of individual works”, and argued that “common work is no more than a side effect of interattraction that gather[s] individuals together” (ibid., p. 100). Nevertheless, Rabaud’s work led to the introduction of two important concepts: interaction and interattraction. Interaction is the reciprocal action where one individual’s action may influence and modify the behaviour of another individual. The concept of interaction formed a bridge between the individual and the social level. Interattraction means that animals belonging to a social species are attracted in a specific way by other animals belonging to the same species. These concepts were further developed by Grassé, whose basic idea was that “sociality is not a trivial consequence that results from interattraction, but a biological characteristic deeply rooted in the ethological heritage of every species” (ibid., p. 101). The action of an individual can provide a stimulus for other individuals, who respond with another action, which is triggered by the previous action. Thus, each individual is a direct source of stimuli for other individuals. In addition, this mechanism allows an indirect coordination of individual activities as each individual’s activities organise the environment

in such a way that stimulating structures are created; these structures can in turn direct and trigger a specific action from any other individual from the same species that comes into contact with them. Chemical trails that are produced by some ants species..., muleteer trail networks, and even dirt tracks and trail systems in man...result from interactions of this kind. (p. 102)

Grassé’s studies of the building behaviour of termites showed that coordination and regulation of building activities does not depend on individual workers, instead it is in fact mainly achieved by the nest structure; the activities in a colony are partly recorded in the physical environment, which in turn is used for organising collective behaviour. Thus the coordination paradox is explained, in terms of stigmergy, as indirect interaction; each insect affects the behaviour of other insects through the use of external objects (building material, etc.) and self-produced chemical...
traces (pheromones). Such means used for indirect interaction are henceforth termed tool use. The introduction of stigmergy provided a step towards understanding and explaining the underlying mechanisms of emergence, regulation, and control of collective activities in social insects. According to Theraulaz and Bonabeau (1999), the main problem in stigmergy is to determine how stimuli are organised, in space and time, to generate robust and coherent patterns. Different colonies of the same species produce qualitatively similar patterns, and in order to explain the mechanisms of coordinating and regulating collective building behavior in a particular way, additional mechanisms are needed. Two such mechanisms are quantitative and qualitative stigmergy. In quantitative stigmergy, the stimuli in stimuli-response sequences do not differ qualitatively. One example concerns the construction of pillars and archs in termite nests, illustrated in Figure 11. The pillars are built of soil pellets, impregnated with pheromone, in two successive stages; in the initial non-coordinated stage, soil pellets are randomly deposited, until one of the depositions reaches a critical size, and stimulates workers to accumulate more material.

![Figure 11. Successive stages of quantitative stigmergy, which leads to the emergence of pillars and archs in termite nests.](image)

The existence of an initial deposit of soil pellets ($S_0$) stimulates workers to accumulate more material through a positive feedback mechanism, and each worker in turn creates new stimuli as a response to the stimulating structure (Theraulaz & Bonabeau, 1999; reprinted with the authors' permission).
Assuming that the architecture has reached state $S_0$ (Figure 11), the coordinated phase, during which pillars emerge, starts; stimulus $S_0$ triggers response $R_0$ from individual worker $I$, who in turn creates a new stimulating structure $S_1$, which triggers response $R_1$ from the next worker $I_n$, and so on. The successive stimuli differ from one another only in the quantity of pheromone present on the pillar. The stimulation functions through a positive feedback mechanism, since ever larger deposits of building material reinforce the attractiveness of deposits through the diffusing pheromone emitted by the pellets. This example illustrates important properties of quantitative stigmergy, for instance the emergence of spatiotemporal structures from an initially random spatial distribution of pellets. The basic mechanism underlying the emergence of pillars is positive feedback, and once the structures are built, they are stabilized by negative feedback, i.e., pheromone decay and competition between neighbouring pillars.

![Figure 12](image)

**Figure 12.** Successive stages of qualitative stigmergy, leading to the construction of a comb in wasps. Each building stage corresponds to the addition of a new cell to a pre-existing comb (Theraulaz & Bonabeau, 1999; reprinted with the authors’ permission).

*Qualitative stigmergy* refers to individuals interacting through, and responding to qualitative stimuli, such as pheromone fields and gradients. In qualitative stigmergy individuals respond with different kinds of action to
different types of stimuli, as represented for example by nest building in wasps (Figure 12); structure $S_{11}$ triggers response $R_1$ by individual $S$. Individual $S$ transforms the structure into a new stimulating structure $S_{21}$, which in turn triggers response $R_2$ by individual $I_n$, and so on. During the nest growth, the number of potential sites for adding new combs increases, and parallel activities may take place, which could lead to a messy construction. Yet the architecture provides enough constraints to direct the building activity and prevent its deorganisation.

Obviously, the use of tools plays a central role in organising collective behaviour. The difference in collective behaviour, when using and not using tools can be illustrated by a simple simulation of the role of stigmergy, for instance, in food foraging behaviour in ants. When an ant finds a piece of food, it carries it back to the nest, leaving a chemical trace of pheromones. As another ant encounters the trace, it follows the trace to the food. As more ants move along the same trail, the chemical trace is reinforced. Let us assume for a while that ants do not make use of tools. Figure 13 illustrates three states of a simulation\(^{55}\) in which no chemical traces are left, and of course, no chemical trails are formed (variables set to 50 ants, diffusion-rate 0.0, evaporation-rate 99)\(^{56}\). The circle at the centre is the ant nest, and the other circles are piles of food. All the ants are moving around randomly and as an individual encounters a pile of food, it carries a piece to the nest, and continues its random movement. Each individual is acting on its own, and no coordinated collective behaviour emerges. As the sequence of images demonstrates, two piles of food (to the right and lower left) diminish at about the same rate, and the third pile (in grey-scaled images: dark grey to the upper left), which is most distant from the nest, is the last to be carried away.

![Figure 133. Simulation of food foraging in ants, without the use of any chemical signals.](image)

The corresponding plot (Figure 14) shows that the amount of food in all three piles start to diminish roughly at the same time, and once a pile has been detected the amount of food in it decreases at a steady rate. We also see that

\(^{55}\) Simulations were run on NetLogo (Wilensky, 1999).

\(^{56}\) The diffusion-rate refers to how much the chemical spreads, and evaporation-rate refers to how fast the chemical disappears.
the pile of food most distant from the nest takes the longest time to collect. Without the use of any ‘stigmergic’ communicational means, no stable trails are formed and no coordinated collective foraging behaviour emerges.

Figure 14. The plot shows what happens over time in this model of ants’ food foraging without the use of tools. The first line that declines represents food in pile 1 (nearest to the nest). The second line that declines represents food in pile 2 (second closest to the nest), and the last line to decline represents food in pile 3 (most distant from the nest).

When the same simulation is run with changed variables, that is, with ‘pheromones’ added, another pattern emerges (variables set to 50 ants, diffusion-rate 62, evaporation-rate 13). Figure 15 shows three states of the simulation, with chemical traces indicated in white and green shades (in grey-scaled images: white and grey). In the first image a chemical trace has been formed between the nest and the two piles of food nearest to the nest, and all the ants are attracted to the same area. In the second image one pile has been carried away, and only a small amount of food remains in the pile to the lower left. The third pile (upper left corner) has also been detected, but there are too few ants in the area to form a stable trace, and due to the distance from the nest it takes longer before a stable chemical trail is formed. As the third image demonstrates, the pile of food most distant to the nest is the last one carried away. On an overall level, we see a stigmergic behaviour, which results in a pattern of organised collective foraging behaviour.

Figure 15. Simulation of food foraging in ants who use chemical traces.

The corresponding plot (Figure 16) shows that the amount of food in the two piles nearest to the nest diminishes rather quickly (the two lines that decline
first), and is carried away faster than in the former simulation. It takes longer to form a stable chemical trail between the most distant pile of food and the nest, but once a sufficiently stable chemical trail has been formed, the pile too diminishes quickly. As the time lines for both simulations show (Figures 14 and 16: 2460 and 987 time steps), it takes longer to carry all the food items to the nest when there is no use of chemicals for communication.

**Figure 16.** The plot shows what happens in this model over time. The two lines that decline first represent food in pile 1 (nearest to the nest) and food in pile 2 (second closest to the nest). The last line to decline represents food in pile 3 (most distant from the nest), which takes the longest time to carry to the nest.

Social insects use a variety of chemical signals (foraging, alarm calls, etc.), and they also use communicative dances (Johnson, 2001; Uhlenbroek, 2002). In some cases different signals are combined, as in African weaver ants. Foraging ants of a colony leave trail pheromones between the nest and a food source, and they perform a wagging dance to tell others about the source and to stimulate nest-based workers to help collect the food. If an intruder appears, the foraging ant stops looking for food in order to fight the intruder. The foraging ant also emits alarm pheromones, which cause others to return to the nest to recruit reinforcements. At the nest, the ants perform a wagging dance, touching others with their antennae, thus transferring the alarm pheromone. Not all the ants depart after this ‘come and fight dance’ though. Instead, some of them stay behind and pass on information about a situation they themselves have not encountered. This behaviour may be considered a case of ‘tooling up’ others, or ‘social tool use’, which was discussed in the previous section. This kind of behaviour is similar to that of social tool use in great apes (cf. previous section), a matter of getting ‘a helping hand’ from others. In the case of apes, however, the tooling up of others is more spontaneous and an ad hoc way of, for instance, solving a problem, while the ants’ social tool use seems more a matter of joining forces for the common good of the colony.

Despite the fact that the insects discussed in this section are social insects, they are commonly considered (individually) to be driven by instinct and exhibit stimuli-response behaviour. However, as noted in Section 3.1.4, Morris (2005) argues that even individual behaviour guided by instinct is in fact closely coupled to that of others, and that coupled instincts differ in behaviour from that of the ‘lone animal’. In social insect behaviour it could be said that individual instincts are transcended through stigmergic
principles. The basic principle in stigmergy states that traces left and modifications made by individuals in their environment may feed back on themselves and others; activities are partly recorded in the physical environment, and this record is used to organise collective behaviour. As the examples show, various kinds of storages are used: chemical traces, building material, spatial distribution of elements, etc. Thus, individuals do interact to achieve coordination at the societal level, but much of their interactions are indirect, and therefore, when observing an individual, it does not seem to be engaged in coordinated, collective behaviour.

4.3 Generalising human and non-human animal tool use

In this section I will abstract some generalisations of human and non-human tool behaviour, based on the issues discussed in Chapters 2-3, and in Sections 4.1-4.2. The issue is not whether or not animals use tools, or the complexity of animal tool use compared to human tool use, but the kinds of tool behaviour found in animals, and how they overlap with human tool use. Generalising tool behaviour is not a trivial task since obviously there are great differences, to say the least, in the species considered here, and their tool uses vary in kind and complexity – natural occurring and modified objects used as tools, combinations of objects, hand-held objects, pheromones, etc. – but the importance is not the kinds of tools involved, or the abilities required for their use, but what they have in common; the way agents make use of environmental resources in interactions, and how that, in turn, affects the agent itself and others.

One could object that even if apes’ tool use in some aspects resembles human tool use, insects are inflexible, driven by instinct alone, and lack consciousness, which leads to the question whether they are really involved in tool use in the first place. That, of course, depends on how tools and tool use are defined, and as discussed in Chapter 2, definitions are plentiful. In Section 2.6, a tool was described as an object used as a means for achieving some purpose (whether the agent is aware of it or not). Tools also extend the capacity of an agent (or agents) to operate within a given situation. In this thesis, it is assumed that the use of external elements (tools and other agents) and self-produced stimuli (chemical traces) are cases of tool use. These are things that are used for some purpose, whether the agent is aware of it or not (insects, e.g., are probably not aware that they leave chemical traces, or that it is for the ‘purpose’ of building a nest). One objection might concern anthropomorphism. Obviously it is necessary to be cautious so as not to ascribe animals with abilities they do not possess. However, it could be argued that descriptions of human behaviour, especially in infants, often are also anthropomorphic in that, e.g., cognitive developmental processes (or whatever the focus) are but inferred from observable behaviours, and certain abilities are ascribed upon them. Therefore, criticism against anthropomorphistic descriptions of animal behaviour, is a criticism that applies to descriptions of much human behaviour as well. However, anthropomorphism should not be a problem in this thesis, since whether or not the cases discussed involve instinct, cognition, consciousness, or something else, is not the issue for the moment. In the following, I will focus
on some generalisations of tool behaviour, and in contrast to descriptions addressing the individual’s tool use, these generalisations are described from a perspective including individual agents as well as a social level of activity.

An agent’s activities are always in relation to others. From a cultural-historical perspective, there is no such thing as an individual activity (only individual action). Instead, all human activities are social activities, an idea that is also echoed in many of today’s situated cognition approaches (cf. Sections 2.2-2.3 and 3.2-3.4). However, typically in comparative studies, humans are compared to the individual animal rather than humans or animals in groups, although group behaviour differs from that of the individual, in both humans and other animals. The isolated individual, or lone animal, is but a theoretical construction, and even animals driven by instinct are coupled to other animals (cf. Sections 3.1.4 and 4.2). Therefore, an agent cannot be separated from its environment, which includes other agents. Individual actions, then, are always in relation to others.

Tool mediation. As strongly emphasised by cultural-historical perspectives, activities are always mediated by (psychological and material) tools, and with the aid of tools, humans control their behaviour from the outside (cf. Section 3.2.1). Furthermore, activity theory emphasises that activity and consciousness are inseparable, and consciousness originates from tool-mediated activity (Section 3.3). However, tool-mediated activity is also observable in animals, even in ones that presumably lack consciousness. Therefore, besides leading to consciousness, tool mediation may have other significant meanings, at a basic behavioural level. Tool mediation in great apes is seen in the process of ‘education by master-apprenticeship’ where skills are mediated through the tool use itself (there is no active teaching; cf. Section 4.1). Other such examples include leaf-clipping and the use of vegetation to indicate travel direction. Tool mediation is also present in social insects, in which coordinated behaviour is achieved through the use of tools (cf Section 4.2). Tool mediation can be direct, as in face-to-face interactions involving a tool, or indirect, where the (asynchronous) interaction is mediated through a tool. Obviously, interactions differ greatly in the species considered here. For instance, humans and apes have much more complex social patterns than insects, and also greater complexity and flexibility in their interactions and tool behaviours. In humans and apes there are also individual variations within group behaviour. While insects have complex behavioural patterns, they do not exhibit hat kind of flexible tool use with individual variations. Yet, in each case there are tool-mediated interactions.

Environment adaptation and triggers. Through stigmergic activities agents also adapt their environment. Environment adaptation is a two-way process in which an agent adapts to its environment (cf. 2.4.3 Baber’s theory of tool use), and also adapts the environment, in other words, agent and environment co-adapt (cf. Section 2.5). This is exemplified, for instance, in the variations in food foraging behaviours between different groups of chimpanzees, and the building behaviour of social insects. As an individual agent adapts its environment, it provides a stimulus for itself as well as
other agents. Thus, the actions of one agent trigger some action in another, etc. As humans adapt their environments, they organise and create spatial and temporal collections of ‘stimuli’, or objects, which in turn generate certain actions (cf. Sections 2.2 and 2.5). Some of the objects in a collection of ‘environmental stimuli’ function as triggers or placeholders, or as both (cf. Section 2.5.1). Furthermore, the way objects are organised, and their properties, in terms of entry points, affect how an agent reacts to them, and which actions they trigger. The same should apply in the case of insects and great apes, although environmental stimuli in these cases probably function as triggers and placeholders, rather than either or. In human agents, self-created triggers may not generate patterns as robust and coherent as in insects, since humans may choose not to respond to a trigger, but on an overall level they contribute to coherent activity.

**Tools and their use prompt and affect future actions.** Tools and their use have temporal aspects in the sense that they are used in a certain way at some certain point of time, they have histories, and they affect future actions. Human tool use is generally affected by the way a tool has been used (its history), and new tools are generally created with some future use in mind. Temporal aspects are also identified in the tool use of great apes as they, for instance, collect stone tools and create tool kits for future use or leave traces for others to follow (cf. Section 4.1). Tools used in indirect interactions among social insects also have an aspect of future use in the way they create (trigger) further actions and affect which actions they elicit. Human agents also actively adapt their environments, creating cognitive scaffolds by re-arranging or creating structures with bearing on future use. An entry point collection, for instance, is a structure that creates future actions, and also affects which actions will be undertaken (although perhaps not thought of in such terms, cf. Section 2.5). Thus, tool use has a temporal aspect in the sense that a tool’s present use creates possibilities for and affects future actions, but the time scale for future actions differs for different kinds of agents and tools. A chemical trace, for instance, which disperses quickly, creates actions on a much shorter time scale than does a tool kit of sticks or stones, or the structures created at a workplace.

**Stigmergy.** As discussed in the previous section, social insect cooperative behaviour exhibits a coordination paradox; when observing individual insects they seem to be working alone, while a group of insects seems to be cooperating in an organised, coordinated way. This paradox has been explained through the principle of *stigmergy*, that is, indirect interaction through the use of tools. Tool use is a means for controlling one’s own and others’ behaviour, and thus collective behaviour is regulated through the environment, that is, each individual’s behaviour is affected by the tools (objects, pheromones, etc.) used by itself or others. While such tool-mediated activity in social insects may not give rise to consciousness, it does lead to well-organised coordinated collective behaviour at the social level. In great apes, an example of such coordination is the use of vegetation by bonobos (Section 4.1). Typically, bonobos travel in subgroups, and a group moving ahead of the others leaves traces (e.g., flattened vegetation or branches stuck
into the ground in an upright position) that indicates the direction of movement. This behaviour can also be explained in terms of stigmergy, where a coordinated behaviour (subgroups moving in the same direction and reassembling at the same location) is achieved through tool-mediated indirect interaction. In many cases humans also interact indirectly through the use of tools (spatial structures, by leaving notes, etc.), which leads to coordinated behaviour. These kinds of interactions are also cases of stigmergic behaviour\textsuperscript{57}. Tool mediation and stigmergy might seem quite similar since both involve tools and mediation. However, while the concept of mediation simply means that activities are always tool mediated, it does not explain how seemingly individual actions actually result in coordinated behaviour at the level of social activity. The principle of stigmergy, on the other hand, provides a solution to the coordination paradox, thereby relating individual action and the social level of activity.

\textbf{‘Tooling up’ other agents.} It is well-known that there are both material and psychological tools (cf. Chapter 3). In addition to these, there is also ‘social tool use’, where an agent uses another agent as a tool. ‘Tooling up’ others means using another agent’s body, or part of it, such as the hand (cf. Section 4.1). Great apes, e.g., can induce another ape to give a helping hand (as exemplified, for instance, in the captive chimpanzees Sherman and Austin, Section 4.1). Social insects also ‘tool up’ others, or get ‘a helping hand’ in food foraging or nest building (cf. previous section). In human agents, tooling up others is quite common – they ask others for all kinds of help, such as asking someone to do something for them, and when using a tool, they can seek others’ help handling it. A difference, of course, is that humans and great apes ‘tool up’ others more spontaneously and it is an ad hoc way of, e.g., solving a problem. In social insects, tooling up others is more a matter of joining forces for the common good of the colony, rather than spontaneous social tool use.

With these generalisations, we conclude the theoretical background of this thesis, and address the two case studies. The generalisations discussed here, will re-appear in Section 5.4, when I summarise the case studies and their relation to the theoretical issues discussed in the background chapters.

\textsuperscript{57} Having referred to Clark (1997) several times, I should also point out that Clark notes in brief that the kind of organisation seen, e.g., in Hutchins’ work (cf. Section 2.2.) is similar to stigmergic behaviour in social insects, but the topic is left without further elaboration.
5. Empirical studies

This thesis contains two case studies conducted in two different work settings. Primarily they were carried out in order to illustrate some of the theoretical issues discussed in the background chapters. While the empirical studies have a common general theme (tool use in a social context), they have somewhat different foci. The first study concerns individuals and their tool use within a social context, and its main aim was to gain insight into the relation between artefacts, individuals, and social cognition. In the second study, the focus changed from individuals in a social context to social interactions and tool use, concentrating on the way tools figure in people’s interactions. Before proceeding into the details of the studies, however, some methodological issues will be discussed. Section 5.1 describes the chosen approach for the empirical studies, trustworthiness, triangulation and crystallisation. The following two sections (5.2-5.3) describe the two case studies on tool use, which are then summarised in the last section (5.4).

5.1 Methodological issues

5.1.1 Approach for empirical studies

Most research in traditional cognitive science has been undertaken from a quantitative approach, while, at the same time, qualitative studies have all too often been deemed to lack “scientific rigour and credibility associated with traditionally accepted quantitative methods” (Horsburgh, 2003, p. 308; Kukla, 2001). However, for the purposes of this thesis, whether one or the other approach is more ‘credible’ or ‘more scientific’ than the other is not really an issue of interest. More important is the question of what kind of approach is suitable for gaining insight into the phenomenon of interest, which in the present case is tool use in social interactions. Nevertheless, the terms qualitative and quantitative have been the focus of a longstanding debate over what is ‘good science’, but the division between qualitative and quantitative research is problematic. The conventional and naturalistic paradigms are often mistakenly equated with quantitative and qualitative research, but quantitative data may be used by a naturalistic inquirer, and qualitative data may be used by a conventional inquirer (Lincoln & Guba, 1985). Furthermore, the division is a misleading one, since regardless whether a study is considered one or the other, analysis and interpretation of data are always qualitative in that they involve ideas about meaning (King, 2004). Even though the terms qualitative and quantitative are troublesome, the conventional use of terms will be followed here.

The case studies described in later sections were not conducted in order to (dis)confirm some theory or hypothesis, instead they were carried out as explorative inquiries. The term ‘situated’ itself already implies a focus on real world events (as opposed to an arranged setting), and exactly what will occur cannot be pre-determined, even though there are initial expectations and questions to guide the study. As put by Lincoln and Guba (1985), a naturalistic study must be carried out in a natural setting because the
things of interest “take their meaning as much from their contexts as they do from themselves” (p. 189). Natural settings are indeterminate, and it is difficult (if not impossible) to know in advance what interactions or patterns will be found. Thus, the research design needs to be flexible to allow adjustments in the approach, for which qualitative methods are more suitable (than quantitative methods) since they are more adaptable in dealing with the unfolding realities (Lincoln and Guba, ibid.). Dealing with an indeterminate reality also requires a flexible instrument, and the most flexible is the researcher him/herself. As described by Lincoln and Guba (ibid.) humans have several characteristics that qualify them as instruments in naturalistic studies. For instance, they can respond to cues in the setting and interact to make them explicit; humans can adapt to situations, tune in on certain factors and collect information about several matters simultaneously; and they can summarise data directly as well as collect feedback from the participants for clarification and correction. These issues are significant in order to gain insight into a naturalistic setting, and given the topic of this thesis, a situated perspective on tool use in social interactions, the empirical approach adopted falls under the label of naturalistic inquiry, or more commonly, qualitative studies. It is also noteworthy that ‘qualitative’ is often equated with certain techniques associated with qualitative research, such as interviews, observations, and so on, even though such techniques are used in quantitative research as well. Thus, what signifies a qualitative study are not the techniques used, but the analysis and interpretation, as well as the conclusions drawn from the acquired data (Janiseck, 2000).

The empirical studies in this thesis may be considered what Stake (2000) terms instrumental case studies. According to Stake (2000), an instrumental case study aims to provide insight into an issue or to draw a generalisation, and it primarily plays a supportive role in facilitating our understanding of something that is external to the case itself. The main aim of the studies was to illustrate (some) of the theoretical issues discussed in the background chapters, issues that contribute to the ensuing framework, described in Section 6.3. Therefore, the studies may be considered of secondary interest in the sense they illustrate something external to themselves, but they are also in depth contextual studies that provide insights into the particular settings.

The kind of sampling chosen for a study depends on its purpose, which leads to different sampling strategies. Two types, described by Patton (2002), are intensity sampling or typical case sampling. Intensity sampling consists of information rich cases that show phenomena of interest intensely, but not extremely, and typical case sampling illustrates what is typical, normal, or average. In both studies the chosen settings are workplaces that include a group of people working together, and where interactions as well as tool use are very common, but not overly intense. In addition, both studies illustrate what is typical or normal, not only in terms of the activities that take place during a regular day of work in respective workplace, but also with the regard to the traits of tool use in interactions outside these particular settings.
settings. While the aim was not to find extreme or unusual cases of tool use in social interactions, but to capture ‘what really happens’, unusual events (in case any would occur) would not be excluded since they could provide useful data.

The studies presented below were inspired by ethnography, especially cognitive ethnography (Hollan et al., 2000), in that they were conducted in natural settings, and “typically ethnographical” techniques, such as interviews, observations (moderate participation; DeWalt & DeWalt, 2002), and video recordings were used. Other sources of inspiration were previous studies on human activities and artefacts in domains such as cognitive science, sociology, ethnography, and anthropology (e.g., Goodwin, 1995, 2000; Hollan et al., 2000; Hutchins, 1995a; Rogoff, 2003; Streeck, 1996; Suchman, 1997). However, the studies were not ethnographical in the strict sense of the word; they were not without pre-specified orientations nor aimed at providing a complete cultural description of, for instance, a group of people or a workplace. Neither were they aimed to be longitudinal ethnographical studies to the extent where one becomes a “cross-dresser, an outsider wearing insiders’ clothes while gradually acquiring the language and behaviours that go along with them” (Tedlock, 2000, p. 455).

Both studies began with general guiding questions, which provided some orientation for their objectives, but the participants were also expected to provide some indication of what should be included in the studies. Goodwin (2000) argues that rather than wandering onto the fieldsite as disinterested observers, attempting the impossible task of trying to catalog everything in the setting, we can use the visible orientation of the participants as a spotlight to show us just those features of context that we have to come to terms with if we are to adequately describe the organization of their action…the participants’ visible orientation provides a guide for what should be included within the frame of the video image, and what materials should be collected from the setting (e.g. the book they are looking at) to facilitate subsequent analysis. (pp. 1508-1509)

Thus, although the studies were directed by some general questions, they remained open to guidance from the participants’ own actions, as well as to additional findings and unanticipated events that could illuminate unforeseen aspects, or contribute to a further theoretical understanding. It was assumed, which is the case in much qualitative research, that as the study progressed, the particulars of the setting that would need further attention would become clearer (Patton, 2002). Since the second study was to be more extensive than the first one, further guidance was invoked by the activity theoretical model of human activity (cf. Section 3.3.3; further discussed in Section 5.3.2). The model orientated the study’s focus towards tasks and procedures carried out individually and by the community (a group of workers), and the tools involved. Yet, both studies may be considered explorative inquiries since not all details were pre-determined nor was it assumed they could be. It was not expected that a neat and ready arrangement of matters would be found ‘out there’, or that the conditions in the settings could be controlled. Thus, a conventional approach of a study
under controlled conditions was not an option. Considering the complexity of a workplace (a ‘natural setting’), and the many details to attend to, I am inclined to agree with zoologist Thelma Rowell (who had been observing monkeys for five years) in her reply to Thorngate, who reveals: ’I asked her if she was planning any experimental manipulations of her subjects. She looked at me in stunned belief: ’Why should I?’ she said, ‘there is so much more to learn by watching!’’ (quoted in Lipshitz, 2005).

5.1.2 Trustworthiness
Regarding the issue of designing qualitative studies, Janiseck (2000) points out that “good qualitative design [is] both rigorous and open-ended”. It is rigorous in the sense that certain techniques and procedures are used. At the same time “good qualitative design” is open-ended in the sense that the researcher is not compelled to look for pre-given specifics. Janiseck also claims that all too often, qualitative researchers are perceived to be just hanging around aimlessly waiting for something to occur, and frequently it is believed there are no questions in qualitative projects. However, qualitative researchers ”have open minds, not empty minds” (Janiseck, 2000, p. 384). Qualitative studies have particular purposes and formulated questions that guide the researcher, even though they are usually not stated as a hypothesis, and they try to be receptive to all influencing factors (Eckert & Boujut, 2003). This leads us to the question of how to establish ‘scientific rigour and credibility’, that is, trustworthiness in qualitative studies.

Commonly recurring issues, which are consistently present whenever methods are discussed, concern validity, reliability, and generalisability, and, as Janiseck (2000) argues, there is a ‘constant obsession’ with this trinity. These terms have their origin in positivism, and with regard to quantitative research, they are central issues for establishing trustworthiness. However, when reassigning the same terms to the domain of qualitative research (see, e.g., Kirk & Miller, 1986), that is, viewing and judging qualitative research through the lens of quantitative research criteria, problems ensue. In fact, it has been pointed out that the “[u]se of quantitative criteria for a purpose for which they were not devised, and for which they are unsuited, has the potential to create the impression that qualitative research does not comprise an academically rigorous approach at least in comparison to quantitative methods” (Horsburg 2003, p. 312). It has been suggested that the conventional terms need to be replaced by ones that are better suited to naturalistic inquiries. Therefore, Lincoln and Guba (1985) suggest that the terms internal and external validity, reliability, and objectivity be replaced with credibility, transferability, dependability, and confirmability. Briefly and simply, these terms may be described in the following way (the interested reader may turn to Lincoln & Guba, 1985, for further details):

- Internal validity, that is, the extent to which extraneous variables have been controlled or ruled out, is replaced with credibility. This concepts refers to the extent to which the researcher’s reconstruction of findings and interpretations are credible from the perspective of the
participants in a studied setting. This requires that a study is conducted in a way which increases the probability of credibility, and to have the reconstruction verified by the participants. The probability of credible findings can be increased, e.g., by triangulation (further discussed below), peer debriefing, and member checks.

- External validity (generalisability) is replaced with **transferability**. A generalisation of results requires the researcher to know ‘the degree of similarity between sending and receiving contexts’. However, any similarity can only be judged by the person who wants to transfer the results to another situation – the original investigator can only provide descriptonal data that allows such a judgement. Thus, the onus is on the person wanting to transfer results to gather empirical evidence about contextual similarity.

- Reliability (consistency, predictability) is replaced with **dependability**. A natural setting, an indeterminate reality, is not predictable, and naturalistic studies cannot be ‘replicated’. Instead, naturalistic inquirers have a responsibility to account for the context of their research, that is, any changes in the matter being studied and those resulting from the researcher him/herself, or the research design, as well as how these changes affect the study.

- Objectivity (i.e., no influence from the researcher) is replaced with **confirmability**, that is, the degree to which the results can be confirmed by the data. Thus, focus shifts from the investigator to the data itself. Confirmability can be enhanced, e.g., by allowing another researcher to examine the results in the manner of a ‘devil’s advocate’.

Regarding rigour, Lipshitz (2005) argues that rigorous research (irrespective of methodology) is the basis for credible explanations. Rigorous research satisfies two principles, namely ‘collect good data’, and ‘draw sound conclusions’. Lipshitz makes some important points regarding these issues, especially when considering that observation is one of the main techniques for collecting data in qualitative research. From a quantitative aspect, collection of ‘good data’ depends on the validity and reliability of the measuring instrument. In the case of, e.g., observations this means the researcher him/herself as the ‘measuring instrument’ must be valid and reliable, which is usually established through the degree of interobserver reliability – the more consistent the reported findings of several independent observers are, the higher the degree of interobserver reliability (Breakwell et al., 1998). Similarly, the validity and reliability of data interpretation (‘drawing sound conclusions’), are established through interrater reliability, and the degree of intrarater reliability depends on the amount of consistency of the data coding of several independent raters. It is assumed that consistency of reporting and coding certifies they are not vulnerable to subjectivity, and that individual views are not imposed (Breakwell et al., 1998). It is also assumed that the degree of reliability can be increased by training observers in order to eradicate discrepancies (Shaughnessy &
Such assumptions are problematic though, as they (implicitly) require that each researcher views world through the same lens, that is, each one has the same kind of background, experiences, knowledge, theoretical commitment, etc. Basically, then, the observer is required to be a recorder who objectively collects ‘raw data’. As expressed by Lipshitz (2005, p. 368):

> It is fair to say that the ideal human observer-cum-recorder mimics mechanical data collection instruments that provide identical readings under identical situations. Employing interjudge reliability to gauge the credibility of an observation system basically extends Turing’s test to the realm of observation: an observation system consisting of several human and non-human observers is perfectly calibrated if it is impossible to determine, solely from the system’s output, which observer is the source of which observation. The premise underlying the notion of the observer as a recorder is that human observers are valuable research tools to the extent that they faithfully collect and report “raw data”, namely uninterpreted objective givens about the phenomenon under investigation.

An important point, regarding the observer as a recorder vs. the observer as interpreter, is that observation and interpretation are not separable – data without interpretation, devoid of any attribution of meaning, would be, as Lipshitz (2005) puts it, ‘a senseless jumble’. Furthermore, the observer as a recorder is restrained to producing “thin, information-poor, categorical reports that are amenable to quantitative analysis and statistical hypothesis testing”, while the observer as interpreter is required to provide “‘thick’... detailed and concrete descriptions, that allow the separation of low-level factual statements from high-level conclusions and interpretation” (2005, p. 371). Thus, the principal contribution of human observers lies in their ability to interpret, that is, ‘see the invisible’, perceive meanings and offer interpretations that others cannot, which is in line with the characteristics that qualify humans as instruments in naturalistic studies (cf. the previous section). This also implies there is no one correct interpretation of observations. Rather, observation and interpretation are affected, for instance, by the researcher’s own background and knowledge, theoretical perspectives, skills, etc. (Agar, 1996). According to Lipshitz (2005), the process of interpretation should be made as explicit as possible and observers should allow their audience to understand:

- what they consider as data
- the method with which, and context in which, data is collected
- the interpretations they give to the data
- the method of transition from data to theory

A related issue, pointed out by Janiseck (2000), concerns a clarification of the researcher’s role. She argues that bearing in mind how qualitative research is perceived, readers need to know, for instance, the relationship between the researcher and the participants, how the researcher’s presence affects the studied setting, and on what basis assumptions are made. Thus a report of a qualitative study needs to present the researcher’s social and physical location, as well as theoretical perspective(s). Thus, in accordance
with Janiseck’s (ibid.) argument, to the above list can be added that researchers’ should allow their audience to understand:

- the researcher’s theoretical perspective
- the relationship between the researcher and participants
- how the researcher’s presence affects the studied setting
- on what basis assumptions are made

Considering the issues discussed in this section, qualitative research cannot be judged by criteria prevailing in quantitative research. Instead, in order to establish trustworthiness, the researcher needs to consider the previously described criteria for naturalistic inquiries, and allow the audience to understand the issues listed above. In conclusion, as Janiseck (2000) points out, it is important to report research in such a way that assumptions and conclusions are clearly supported by the obtained data, and adhering to the data is the most powerful means of ‘telling the story’.

5.1.3 Triangulation and crystallisation

One way to increase credibility is triangulation. The advantage of triangulation is that a combination of methods, researchers, data, and (or) theoretical perspectives leads to more reliable conclusions (Denzin, 1978; Williamson et al., 2002). For instance, one method can compensate for weaknesses in another, and the combination of different data sets enables cross-checking and parallelizing of data. Interviews, e.g., are valuable because they provide a means of gaining knowledge on certain issues as well as participants’ perspectives on topics of interest. Observation is a logical complement for gaining first hand knowledge of situations, something that can be difficult to obtain solely through, for instance, interviews, or by participants’ own descriptions of their activities. What participants say they do does not always coincide with what they actually do. Furthermore, some actions and interactions, are implicit and difficult to verbalise by participants, but they may well be observable. A possible disadvantage with observations, of course, is that things could be missed, especially when taking notes. Video recordings therefore, provide yet another useful complementary technique because they capture real world events and their dynamics, as well as details that could be missed through observations (by watching) (McNeese, 2004; Xiao & MacKenzie, 2004). Video recordings can also be viewed several times, from different perspectives, and therefore they provide a “second memory” that can be consulted at convenience, and an opportunity for detailed frame-by-frame analysis (if necessary). The combination of several such techniques provides a means of gaining insight into the interactions between people and their use of artefacts, and subsequently cognitive processes.

Triangulation has become something of a buzzword, and even though it may provide a powerful way of validating findings, it has a disadvantage in the way it implies an assumption that there is a precise, fixed point to triangulate, and that the world may be approached from “three sides”. It is as if validity resides in the triangle, a rigid, fixed, two-dimensional object.
Richardson, 2000). An alternative way of viewing qualitative research design has been proposed under the label of crystallisation. According to Richardson (2000), a major advantage of crystallisation, in comparison to triangulation, is that it recognises the world can be approached from many more than three ‘sides’; a crystal “combines symmetry and substance with an infinite variety of shapes, substances, transmutations, multi-dimensionality, and angles of approach. Crystals grow, change, alter, but are not amorphous” (p. 934). Therefore, which of its ‘facets’ we view, what we see, depends on the angel of the crystal. Subsequently, a particular (work) setting may be viewed from different angles in order to gain a deeper understanding of what is happening. Richardson also adds that “[c]rystallisation, without losing structure, deconstructs the traditional idea of ‘validity’...[it] provides us with a deepened, complex, thoroughly partial, understanding of the topic” (p. 934). However, although the term triangulation implies an approach from ‘three sides’ (three methods, three researchers, etc.), it seems that the very idea of combining things (whether there are two, three or more of them) is more important than the number of things actually combined (see, e.g., Denzin, 1978; Patton, 2002). From a situated/embodied cognition perspective, human activities are certainly not ‘fixed points to be triangulated’ or something that is approachable from ‘three sides’. More important, however, is the notion of combining methods etc. as it renders a more nuanced view of the subject of study than would be the case if, e.g., only one theory or one method was used. Disregarding the implied assumption of ‘three sides’, this thesis combines different theoretical perspectives, and uses different techniques for data collection in the case studies, as well as several data sources in the following analysis. With regard to the issues discussed, it might be argued that from a situated perspective an empirical study can take triangulation as a way of compensating for weaknesses or limitations in data collection and analysis. Furthermore, bearing the crystal metaphor in mind allows us to recognise that a setting (people, tasks, patterns, etc.) can be approached from different angles. This enables us to arrive at a rich understanding of the events taking place in a studied setting.

5.2 Case study I: Individuals, tools, and social interactions

5.2.1 Setting the scene
This section describes an initial study of the use of tools in a social context. As discussed in previous sections, most research on cognition and tools/artefacts has mainly focused on the individual, while contextual and environmental aspects have been largely disregarded. Subsequently, there is limited understanding how artefacts affect the individual within a social context. The fundamental aim of this study was to consider the individual’s tool use within a social context in order to gain further understanding of the relation between artefacts, individuals, and social cognition. Accordingly, the underlying question for the study was “how does tool use affect individual

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58 Much of this section appeared in similar form in Rambusch, Susi and Ziemke (2004). The empirical part of the study was carried out by the first author as part of her B.Sc. dissertation (Rambusch, 2003), which was supervised by Susi.
cognitive processes within a social context?”. ‘Tools’ in this study refer to objects that are significant for everyday work tasks, that is, objects that are used (knowingly or unknowingly) in order to achieve some purpose (cf. the description of tool and tool use in Section 2.6). ‘Cognitive processes’ refer to high-level processes such as attention, memory, and coordination.

The study was conducted at the admission unit of the children’s ward at the Swedish hospital KSS (Kärnsjukhuset i Skövde). After initial contact with the head person, a meeting took place with the staff members. They were informed a study was to be conducted at the office, and the staff members consented to their participation in the study (those not present were informed in writing). Different techniques were combined for data collection, in order to gain knowledge into the interactions between people and their use of artefacts, and subsequently cognitive processes (cf. Section 5.1.3). Initial interviews were conducted during the first meeting to obtain information about the staff, their work tasks, and the organisation of the office. Observations were made during two days (moderate participation; DeWalt & DeWalt, 2002). Meanwhile notes were taken and, when necessary, questions were asked (e.g., to clarify the meaning of some procedure or task). The office was also videotaped during the observations (three hours in total). The videotaped material and notes taken during the observations were analysed from the perspective of the staff’s work tasks and activities, as well as the function of the artefacts used in relation to the identified pursuits. When the data analysis was completed, another interview took place to verify, e.g., that work tasks had been correctly understood.

The participants of the study (staff members) were told that all material concerning them would be treated confidentially. It is a somewhat sensitive matter, however, conducting a study in a setting where patient information is handled. Of course, all patient information is strictly confidential, and therefore written agreements of confidentiality (concerning all material involving patient information encountered during the study) were signed. Since all videotaped material also must be treated confidentially, it could not be saved (for future use), and therefore, once the analysis was completed, the tapes were erased.

5.2.2 Overview of setting and work processes
Workplaces such as the children’s admission unit are indeed highly social environments in which the effective daily work routines require well-organised cooperation between the staff members, as well as the different wards. The work tasks of the children’s admission unit are individual in the sense that most of the work is carried out individually. For example, parents and children arriving at the admission’s desk would usually first meet an administrator who registers their arrival, then a nurse who, for example, might draw a blood sample, and eventually a doctor. At the same time, however, all these individual tasks are, of course, socially situated strongly coupled to the social and environmental context.
A part of the central office of the children’s admission unit was chosen as the setting for the study. The office has three sections: a reception, an administrative unit, and a unit where all incoming phone calls are handled. The study was limited to the administrative unit (Figure 17), which functions as a communication, coordination, and administrative centre. As such it is a central place for much of the daily activities, and frequently visited by nurses. There are always three to four nurses working at the same time, and the study focused mainly on their tasks. However, other people also visit the administrative unit during the day, e.g., doctors who collect patient records.

Figure 17. The observed administrative unit. In the upper corner is the small table with a tray on top (follow-up instructions), and labelled ones on the shelf below. The patient list(s) is on the left wall above the table. On the bench to the lower left is the (orange) tray for filled-in sample documents. The two cameras indicate the (one) camera placements used during the observation.

The nurses’ work mainly consists of taking care of patients that have an appointment, as well as any urgent cases that may appear during the day. They also handle administrative duties, phone counselling, and patient-related tasks, for instance, drawing blood samples. Each member of the staff is responsible for certain tasks, but must also be aware of the others’ duties and responsibilities in order to coordinate their work. At an overall level, the daily routine consists of registering patients on arrival, and retrieving each patient’s medical record from the archive. Patients expected during the day are listed on a patient list. An initial examination (weight, etc.) is carried out by a nurse, and if the patient has a doctor’s appointment, he or she is shown into a consultation room. In cases where some kind of a sample needs to be drawn or collected, the doctor notifies a nurse.
5.2.3 Significant tools

The children’s admission unit is a highly social work setting, which requires well functioning cooperation, interactions, communication, and shared knowledge of routines as well as others’ tasks. The staff members use a number of artefacts with various functions, which require additional interpersonal knowledge. It became apparent that a number of tools were crucial with respect to processes such as the coordination of ongoing work. In the following, some artefacts are discussed in more detail.

To begin with, most activities in the administrative unit take place around a small table (Figure 17) on which various items are kept, some only for a short time and others for longer. It might seem trivial to discuss a small table placed in a corner, and typically it is one of those objects taken for granted to the extent that it becomes ‘invisible’ (cf. Section 2.2). However, the table is part of the office unit’s structure and (together with other such equally ‘invisible’ items) plays a crucial role in the organisation of the daily work by drawing attention to what is happening, what needs to be done, and it is the place where often used or needed things are kept. The table is an important part of the spatial arrangement that contributes to the overall structure of work tasks (cf. Section 2.4); members of the staff know it is where often used and needed items are kept, and a place for important information. Thus it provides, e.g., an external memory; people often glance at the table before leaving the room, to check for anything they may have left there as they entered the room (as is often done), or if there is something they need to deal with. The table is also used as a message board, where notes are left for others.

Among other items, one of the most important objects in this setting is the patient’s medical record. Basically, it is a folder containing a collection of documents with information about a patient. All the documents are sorted in a specific manner in order to facilitate finding the right information (a document out of its proper placement causes disturbances in the work-flow). When a patient visits the children’s admission unit new information is added. The patient record has several functions, besides the obvious one of storing information about a patient. Clearly, no single person could keep all the patient information in their head, and since the patient record provides an external memory, there is no need to either. During the interview it was revealed that on some rare occasion a patient’s medical record has been misplaced, which caused serious problems. During the patient process, as different people handle the patient record, more information is added, and its contents (the representations) become transformed. Generally, patients do not meet the same nurses and doctors each time they come to the children’s ward, but information concerning the patient is transferred between staff members through the patient record, which thus functions as a ‘communicator’ between different people. In this way, the contents of a patient’s record transform intrapersonal knowledge to interpersonal knowledge shared by several people. The patient records also contribute to an overall coordination of work processes since, depending on its placement, it causes different people to take different actions. A patient record in the
reception’s tray triggers a nurse to bring it into the administrative unit, while placed in a tray labelled with a doctor’s name it informs him/her that a patient is waiting, etc.

Another highly crucial tool is the patient list placed on the wall above the small table (Figure 17) (another list in the reception was not included in the study). The patient list actually consists of nine smaller lists, each corresponding to a consultation room which the same doctor uses throughout the day. Hence, the list informs, not only who is coming and when, but also in which room the patient will be received and by whom. The list also contains information about each patient and the measures to be taken. Although the patient list is computer-generated, during the course of the day the nurses make additional marks by hand, typically understood only by the staff (cf. 2.4.2). For instance, a certain mark next to a name on the list indicates that the patient is waiting in the consultation room (which the list concerns), another means a doctor is delayed, and yet another one informs that the patient has left the ward. All markings are made in red so that they are highly visible and easy to perceive. During the observation it became clear that the nurses have no difficulty understanding the added symbols, and thus the list provides a means of communication and coordination between people, even when they do not interact directly.

Besides functioning as a means of communication and coordination, the list also constitutes a (shared) external memory, providing everyone with the same necessary information. No one needs to memorise the information, as it is ‘there’ all the time, visible to those who need it, when they need it. As symbols are added to the list, the information is transformed and communicated from one individual to another when needed (cf. Section 2.2). The list also provides a visual overview of the consultation rooms. Thus, each doctor only needs to pay attention to the one part of the list related to his or her room, which in turn limits the amount of information that needs to be attended to.

There are a number of different kinds of trays for various papers in the office, each with its own function and assigned meaning. As patients are registered on their arrival, their medical records are withdrawn and placed in a document tray in the reception. A patient’s record in the tray is a signal to the nurses that a patient has arrived. The patient’s record is taken by a nurse to the administrative unit, and, eventually, it is placed in a tray labelled with the name of the doctor the patient is going to see. Usually there are four to five doctors working at the same time, and their labelled trays are placed on a shelf under the small table (Figure 17). Trays belonging to doctors not on duty are placed on another shelf (top one to the left of the small table, Figure 17). During the day each doctor collects the patient records that are placed in his or her tray. When a sample needs to be drawn or collected, this is notified by the doctor leaving follow-up instructions in a blue tray (to the right on the small table in Figure 17). When a nurse has performed the procedure, a filled-in document concerning the sample is placed in an orange tray (on the desk to the lower left in Figure 17). Thus,
the spatial arrangement of the trays contributes to structuring the ongoing work.

Besides containing documents, the trays have several other functions. For instance, rather than having to memorise each ongoing process of the workplace, the trays, and their contents, provide information about what is happening as well as matters that need attending to, thereby providing an external memory. The trays also provide a means of indirect communication between individuals. The nurses, for instance, do not have to personally inform a doctor that a patient is waiting. This information is mediated instead through the contents of the labelled tray. In this way each person can attend to his or her own individual work tasks, while at the same time, at an overall level, the indirect communication contributes to a well-organised process. The trays also limit the amount of information that needs to be considered. A doctor, for instance, only needs to pay attention to one labelled tray, or one part of the patient list.

5.2.4 Tools and interactions
The question guiding this study was “how does tool use affect individual cognitive processes within a social context?”. Since time spent on observation in this setting was limited, so was the amount of data yielded and, subsequently, the analysis was less extensive. Despite possible limitations, however, the study provided a reasonable understanding of some of the ways people make use of artefacts within a social context.

At a general level, the study demonstrates the importance of the tools used in this particular setting, and the way they contribute to a well-functioning organisation where many of the activities are coordinated in an implicit manner. The power of the tools used in this setting becomes evident only when considered within the social context in which they are employed (cf. Section 2.4.2). The patient lists, for example, are logical only to, and understood by, those who use them. The study also revealed that not only the way tools are used is significant for cognition, but also their spatial arrangement, that is, where they are used (cf. Section 2.4). The environmental structure and spatial arrangements partly determine the function and the meaning of, for instance, the labelled trays, the purpose of which varies depending on where (which shelf) they are placed. In addition, patient records trigger different activities depending on their placement. Tools also provide a scaffold for various cognitive processes depending on who the user is, that is, the user’s role in the overall social arrangement. Furthermore, tools have an important function as organisers. The state of a tool, for example, if a tray is empty or not, helps the individuals to organise their work, and on the social level it contributes to coordination, cooperation and structure. Some tools make information available and visible, thus contributing to its propagation between people and the things they use.

As discussed in Section 2.2.2 on distributed cognition, the activities of a group cannot be fully understood from the individual’s perspective, and individual actions cannot be explained without considering the actions of
others, which include the interpersonal codes, knowledge, and shared understanding of the functions of all the artefacts they use. Another important aspect is the way tools transform individual processes into social ones, and vice versa. For instance, when a nurse marks the patient list the information becomes part of a social activity and individual knowledge becomes shared knowledge (in a sense propagated ‘on demand’ only). Likewise, social or shared activities may become individual actions, e.g., when the nurse responds to the information added by others.

In summary, the tools analysed in this study function as mediators of distributed social cognition, i.e., they facilitate shared memory and information, coordination, and communication. Many tools have the same or similar functions, but the functions vary depending on who is using the tools, where (spatially) they are used, their functional coupling to other artefacts, and the social context. Furthermore, in many cases the tools transform social interactions into individual processes, but at the same time they also mediate the indirect interaction of these processes, and thus maintain their social nature. This study has illustrated that in order to understand tools and their role in individual and social cognitive processes, we need to consider tools, individuals, the social context, and their functional interrelations. Thus the study clearly demonstrates, which is also discussed in previous chapters, that individual tool use is not an individual enterprise. Although tasks are often carried out individually, it is within the wider frame of social processes and the social context that tools and their use assume their meaning.

5.3 Case study II: Tool use in social interactions - a joint effort

5.3.1 Setting the scene
While the first case study (cf. previous section) took individuals and their tool use within a social context as a starting point, in this second study the issue is extended to consider tool use in social interactions. This study is also described in much more detail than the previous one (further discussed in Section 7.2). The general guiding question for this study was what is the role(s) of tools in social interactions? Interactions in this case refer to direct (face-to-face) and indirect interactions between people. Tool use refers to the use of external resources, that is, objects perceived by people as tools, and which are used as a means for achieving some purpose (whether people are aware of it or not). These are objects that scaffold individual as well as distributed cognition, and extend a person’s capacity to operate within a given situation (cf. Section 2.6).

The study was conducted in the control room of a middle-sized Swedish grain silo (Svenska Lantmännen ekonomisk förening). This particular setting can ‘facilitate our understanding of something that is outside the case itself’ (cf. Section 5.1), that is, it is a natural environment in which events of interactions and tool use can be studied. It is considered a suitable setting

59 Parts of this case study were reported in Susi (2005c).
because the area of observation, the control room itself, is naturally spatially limited, and while there are sufficient workers for interactions to take place, there are not too many so as to lose track of what they are doing. My presence at this particular work setting was eased by the fact that the head of the plant and I already knew each other – he was my pass into this special arena. I had also met one of the other workers previously on a few occasions. This eased my relationship with the other staff members who were reserved at first. It is not always recommendable to conduct a study at a place where researcher and participant(s) know each other. Potentially, it could be difficult to keep apart one’s observations and one’s pre-conceptions. Likewise, a participant’s behaviour could be affected by his or her prior knowledge of the researcher. In this case, however, it was a tremendous advantage. The staff at the silo and their customers (mainly farmers, and truck drivers hired for transporting grain) are, what might be described as down-to-earth people, and some are not too impressed with academia, white-collar workers, etc. Subsequently, being a researcher, I was considered a somewhat ‘suspicious’ character. Over the following days, however, as they became aware that I was acquainted with the manager, they began to regard me as ‘one of them’, that is, a regular person rather than some academic observing what they were doing. It is also noteworthy, in defence of critics to the fact that researcher and participant knew each other, that the manager is one of those who appears the least in the recorded material.

The study was conducted during the harvest season, the most active time of the year, with staff working more or less around the clock. A total of seven people were employed at the silo during this harvest, with 2-3 people working at the same time in two or three shifts. Six of the staff members participated in the study, two women and four men. Their ages varied from 19 to 60 years, and their experience of working in silo control rooms varied from none to 26 years (two of the workers were highly experienced, four were novices). The study’s duration was 3 weeks, in the course of which interviews, observations, and video recordings (8 hrs in total) were conducted. The time I spent in the control room was limited by two factors; the consent of participants (further discussed below) and weather conditions. Most deliveries are made when the weather is favourable (no rain), in which case the staff is occupied with tasks in the control room. Rain, on the other hand, means few or no deliveries and the staff works mostly on plant maintenance. Subsequently, there was really no reason for my presence on rainy days as little of interest for the study could take place.

The staff had been informed of the study at their workplace, and the date I would appear. During the first meeting with the employees, the purpose of the study was described as an ‘interest in work processes and the things people use in their work’. They were also told that my interest was the work as such, and not their individual efforts. It was specifically pointed out that the study was not conducted on behalf of the company, it was only for research purposes and all material would be confidential (unless agreed

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60 The number of seasonal workers is based on the estimated size of the year’s crop, and may therefore vary from one season to another.
otherwise). During the first meeting some demographical data was also collected (age, experience, etc.). All staff members, but one, whom I met a few days into the study, gave their consent to participate, and no one opposed the use of a video camera. The purpose of the study was deliberately kept very general in order to avoid affecting the participants’ behaviour, and to refrain from guiding their awareness to certain matters by explaining exactly what I would focus on. Of course, people are probably affected, at least to some extent, by the mere presence of an outsider – after all, most of us cannot but be aware of someone observing our work. After a short while, however, the staff did not seem to object to my presence.

Initially, there was an informal interview with the manager of the plant in order to gain an overall understanding of the setting, that is, the general work procedures and tasks. Additional information was collected during the observations from other employees, through informal questions and discussions, when time allowed (e.g., between deliveries). A small digital tape recorder was used on such occasions. The tape recorder was also very useful in situations when people spontaneously began revealing such matters as how the silo has evolved over the past decades. Parts of the recordings were transcribed for further analysis.

What to include (and what to leave out) in a study cannot always be decided beforehand, but using the model of human activity for orientation (i.e., some of its elements, further discussed in the next section), my observations were focused on the work tasks and the tools used in them. Of course, not every single task and tool could be included, and over time the staffs’ own actions provided guidance to matters requiring close attention. From their actions it became clear, e.g., which material objects (of all the things in the control room) that had relevance for ongoing activities. Field notes were taken from the very beginning of the study, e.g., on general procedures, certain tasks, and the objects people were using (e.g., what the whiteboard was used for) (see appendix, Figures 33 and 34). Quite soon, however, it became obvious that taking notes was an inadequate technique of data collection of unfolding events in this setting. It proved an impossible task keeping track of several people, their use of tools, and, at the same time, record events in writing with enough detail to make sense of a subsequent analysis – a lot of data is lost in such a process. For instance, Figure 35 in the appendix, shows field notes written while grain was transferred into the silo and a sample was to be taken. The notes mainly describe the procedure, and very little about who is doing what, and nothing about the timescale or synchrony of people’s actions. Therefore, the main volume of data was collected by video recordings. Much time was spent on observations (notes were written directly after, rather than during the observations) to gain a general understanding of the setting as such, people’s interactions, the tools used in their work, and the reason for their use. Several informal conversations about work tasks, the control panel, the machinery, etc., also took place during the observations. During the analysis the videotapes were viewed several times, and parts of them were also transcribed; conversations were written down word for word, along with comments about people’s activities.
(see appendix, Figure 36). Also, observational notes, interview data, and videotapes were compared to ensure that collected data was coherent. A follow-up interview was also carried out to clarify some details (e.g., were some documents finally end up). The quotes from participants that appear in the following section have all been translated from Swedish by the author.

5.3.2 Work in the control room

This section begins with a few words on the general model of human activity, which then orients the following description of the work tasks and processes that take place in the control room. This section ends with a short summary of my impressions from the observations.

The general model of human activity (or activity system), discussed in Section 3.3.3, can be used as a frame for what to include in a study and its analysis. The model includes a number of elements regarded as the constituent elements of human activity, and it considers the elements in relation to each other. Obviously, there are several work processes taking place simultaneously in the silo, e.g., transportation of grain into or out of the silo, sample analysis, maintenance (electrical, repair of machinery, painting, etc.), planning meetings, cleaning, etc. However, not all tasks will be discussed here, instead the focus will be on one central procedure and the tasks related to it; the process of conveying grain into the silo.

With the activity model as a basis, the activity of grain transportation can be described in the following way (Figure 18): The activity consists of the transportation of grain into the silo by the staff. The object comprises the grain off-loaded into one of the pits, which is to be transformed into grain stored in a silo. The subjects are the individual workers, and the community consists of the staff members sharing the object. There is a division of labour between employees, between staff and clients, and between the head of the facility and subordinates. A set of rules covers what it means to be a member of this community. Some rules are explicit and formal, such as safety regulations. Others are informal, like agreements on how to carry out the work, or the culture that develops as staff members work together. There are a number of tools used in the transformation process, such as documents, phone lists, scale displays, control panel, computer, and whiteboard (there are of course also psychological mediating tools, but the main focus here is on external material resources).
The following description focuses on the elements ‘subject’, ‘community’, and ‘tools’. The context in which these elements are described is the transportation of grain from a pit where it has been off-loaded, into a silo in which it is to be stored.

During the harvest season, grain is delivered from local as well as more distant farms. The unloading and transportation of grain into the silo is coordinated by the control room staff (2-3 people working at a time in different shifts). There are up to a hundred deliveries per day of (up to) 11 different types of grain, which are stored in 29 silos (for the sake of convenience the whole plant is mostly referred to as ‘the silo’). With all these variables mistakes are easily made and can be very costly. One such costly mistake is to (accidentally) convey different kinds of grain into one and the same silo – an error that can cost some 70 000 $, since mixed grain has little or no value and is almost impossible to sell. Such incidences mostly ensue from the operations performed on the control panel (further discussed below).

When seasonal workers first arrive at this workplace, the regular staff members explain and demonstrate how to perform various tasks, and the novices watch, ask questions, practice by themselves, and learn as the work progresses (Figure 19). There is formally written information concerning some tasks (e.g., which types of grain to accept for delivery, and instructions for grain analysis), but it is not often used. For most of the tasks there are no written procedures at all, mainly because, according to the staff, they require flexibility and knowledge of how things function in reality (especially tasks involving the control panel). How much guidance new employees need varies from one worker to another. While some require repeated explanations, others find it “easier to learn by just watching”, as one of the seasonal workers explained. All the employees do all the tasks that are usually carried out in the control room, for instance, meet clients, handle documents, take samples, and operate the control panel. Quite often, however, the experienced workers are elsewhere in the plant, maintaining
machines and repairing break-downs. Therefore, most tasks in the control room are often carried out by seasonal workers. Early in the study it was noticeable that the way these tasks were performed differed between the seasonal workers and those with more experience. Even though the study was not concerned with expertise or ‘experts’ vs. ‘novices’, there clearly were differences which, as we will see, affected the way various tools were used, as well as the work processes at a general level.

Figure 19. Control panel in the control room of the silo. The panel represents the whole plant, e.g., silos (‘circles’ that the worker is pointing at), and transportation shafts (vertical and horizontal lines). An experienced worker explains the control panel to one of the seasonal workers.

One of the most central and important tools in this setting is the control panel, from which basically all the mechanical processes are operated (Figure 19). The way the panel is understood and operated clearly differs depending on the employees’ previous work experience. Seasonal workers usually learn to use the control panel in a few hours (or at least a few days), that is, how to start and stop transportation processes, which consists of pushing a sequence of some 10-15 buttons (depending on the state of the machinery). There are three lines in different colours (representing transportation shafts) along which the buttons are placed. The workers described two of the lines as the ‘easiest’ part of the panel, since starting those is usually a matter of tracing the coloured line on the panel and pushing the buttons along it. The third line was considered more ‘difficult’,
since it contains more options, which also increases the risk of making errors. In general, however, the control panel itself is not considered very complicated. The complexity of operating it is knowing and understanding the underlying machinery, and the relation between machinery and the panel’s buttons and switches. As an experienced worker explains it (his emphasis in italics and clarifying comments in brackets),

...the panel...takes a couple of hours for one who’s alert, but that’s not what it’s all about really, it’s about knowing what happens when these things happen here [he refers to a machine failure earlier that day]...and out in the plant...one must know where to go, and “where is this?” [to what a button corresponds] and “these things, what do they do?” [the effects of buttons]...if something goes wrong you must know where to go....that’s the knowledge, this isn’t knowledge, to sit here and look at the buttons...two hours!...takes something of a jack-of-all-trades to keep something like this running...

The complexity of the knowledge required is evident from the fact that it takes 2-4 years to learn how to operate the control panel/machinery (and to ‘see’ whether or not everything is working) properly. The crux of the matter here is that while the control panel represents the whole plant, the mapping between the representation and its underlying machinery is inadequate. Before the event of control panels, there was a chalk board (in every control room) with a representation of the silos, used for noting the types of grain in them, but chalk board and machinery were two separate things (Figure 20).

**Figure 20.** Chalk board of the type used in all control rooms before the implementation of today’s electrically operated control panels. It contains a representation of 21 silos.

With technical development, control panels with integrated representations of silos and machinery were implemented. Subsequently, over a period of some 10-15 years new technical features, and their representations, have
been increasingly added. The silo was originally built at a time when there were only four different kinds of grain to handle, and the same worker explained that it used to be easier when grain could be put directly into one of the silos, without having to “manipulate the machinery” too much. Today there are eleven different types of grain which require a flexible use of transportation shafts, from three different pits to the 29 silos. With all sorts of grain stored in the silos, one single load often has to be conveyed through more than one shaft before it reaches its final destination. There is no fixed way to handle the machinery (and the facility as such), and there is an unspoken or tacit agreement that things can be done in different ways, and that people have their own ways of doing things. As one worker explained, referring to the process of drying grain, “it is smooth to run it this way…this is how I run it, but somebody else may run it in a different way”. The same worker also said:

Everything is so complex…the machines, and what we’re dealing with here are from 1967…things have been added to the panel and it’s been remade a number of times…and we have all the sources of error following from that...

...from the 50s until some...ten years ago...everything was operated mechanically [in silos in general]...one went in and started things here and there in the plant...hatches were regulated by pulling ropes...that was the 50s, then we got engines for opening the hatches...[the way] many things are operated and controlled remain from the 50s...

Therefore, knowing how to run the plant is knowing and understanding the control panel as well as the underlying machinery, and the functional relationship between them.

As seen in Figure 21, the control panel holds a number of indicators (with light on or off), hand-written notes, and magnetic plaques. Turned on indicator lights signal which processes are running, and some lights alert, e.g., when a silo becomes full. Such alerts are also connected to sounding alarms. On the magnetic plaques are texts which indicate the different types of grain being stored as well as ‘hatch out of order’, ‘open’, ‘closed’, ‘empty’, ‘full’, ‘repair in progress’, etc. They are used on the control panel to show what is stored in which silo, as well as the status of the silos and machinery (the plaques not in use are kept on a whiteboard next to the control panel). The magnetic plaques are in five different colours and of varying shapes. There was no detectable colour coding (which I first assumed to be the case), such as a certain colour for grain or a particular one for machine related events. When asked about the colours, one of the experienced workers revealed that all plaques used to be yellow (when he came to this silo a few years earlier), but “that’s not good, everything blends into a mess…it is difficult to see anything”. In order to ‘see’ anything, they had to read the text on each plaque. Therefore, they made new magnetic plaques with mixed colours and texts.
Often there are some handwritten notes on the panel as well (Figure 22). A note may read, e.g., “repair in progress” and be placed over a button in order to prevent anyone from pushing it. Another typical kind of note concerns the moisture content of grain in some particular silo, and may read, e.g., “silo 16, 18%” (sometimes a date is added as well). In this case the moisture content is way too high and, as told by one of the workers, they use such notes to remind themselves, and others, that there is wet grain in that particular silo. This acts as a reminder not to place dry grain in the same silo, and that the grain is wet and needs to be handled within the next few days. The staff can wait before starting the drying process if they know more of the same kind will be delivered, but how long they wait mainly depends on the degree of moisture (all grain is generally termed ‘wet’ or ‘dry’, and the moisture content of dry cannot exceed 14%). Yet, there are problems with ‘mixed grain’ every year. As explained by one worker, not all kinds of operations are possible since there are constraints built into the system (the machinery), but it is possible to do wrong, especially at the end (i.e., to push wrong buttons at the end of the coloured lines that represent the transportation shafts).
When novices learn to use the panel, they are told to trace the line they are going to use with a finger, and push the buttons along it. When a button is pushed the light comes on, then the next button can be pushed, and so on. Some buttons, however, do not light up at all (for some unknown reason according to the staff), and sometimes a light may just be out of order. Furthermore, some lights turn on immediately the button is pushed, while others take a few seconds (the light must turn on, if it is one of those which does, before pushing the next button). Where lines cross they have to learn which buttons (in the intersections) to push, or not. They also have to learn which lights (should) turn on or not, and which ones turn on only after some delay. Then they must double check to make sure that it is correct. Only then can they push the last button that starts the whole process. The appearance of the control panel itself makes its operation difficult to learn, which contributes to mistakes in the first place. As one of the employees said, as he was scanning the control panel, “what does one do, and why, and when...and how? You have everything in control to 90 %...so there is room for error...100% is difficult”. Another contributing factor is that workers with little experience just do not realise the effects of all the buttons. As one of the novices said, “I don’t know what some buttons are for, but I push them anyway because they’re supposed to be pushed’. Another employee, however, who actually preferred watching to asking too many questions, said “it is better to ask twice and...seem a bit stupid than make a mistake, it is
actually”. Nevertheless, mistakes are made and grains become mixed, especially when workers are in a hurry. The experienced ones told how they often check the control panel and find that everything is not correct. One of them also confessed that they themselves (the experienced ones) sometimes make mistakes, because when workers become too self-confident they stop checking themselves. Therefore, it is really important, as he said, to “double check oneself”.

On many occasions the experienced workers, as they came and went in the control room, briefly looked at the panel and pushed some button on the run. When asked what they did, and why, their usual answers were “it was wrong”, or “the hatch was open” (when it should be closed, or vice versa). After some such occasions, the less experienced worker (or workers) looked at the panel, seemed confused, and thought for a while. In some cases they commented that when they thought it through, they could ‘see’ what had been wrong, but in others they did not ‘see’ or understand what had been wrong, and asked about it later. So, when there was an indication on the panel that something was wrong, the novices often did not recognise it, even though they carefully checked the panel. On other occasions, however, they could ‘see’ that something was not right, but were not able to pinpoint the problem. Experienced workers often noticed more easily when, and what, was wrong.

Before arriving at the silo, farmers and truck drivers call to book a time for delivery. Any worker present in the control room may answer the call, and they use a phone list (Figure 23) on which they note who will deliver what, when, and how much (in order to know how long the off-loading will take). The list is always kept in a certain place on the desk, within reach when answering the phone. Phone lists are used for two reasons. Firstly, they prevent long queues, since the staff can allocate appropriate time slots for delivery (as told by one of the older workers, before the use of such lists queues could sometimes be very long, and people had to wait for hours). Secondly, phone lists are used for planning the day’s work. Knowing what, and roughly how much will be delivered during the day allows the staff to plan the storage of grain. Such planning is important, because when some of the silos are in use, grain from a certain pit cannot be conveyed, bypassing the occupied silos, to the other ones due to the construction of the machinery. Therefore, the allocation of delivery time slots requires that several aspects are taken into account: deliveries already noted on the list, the incoming calls, and the status of the silos. Furthermore, adequate planning requires knowledge of possible ways of maneuvering the flow of grain through the conveyance shafts (how to ‘manipulate the machinery’). On several occasions novices did not consider all these factors, but instead booked the first time slot available on the list. The more experienced workers occasionally check, not only the list, but also the control panel, and plan ahead how to handle the incoming grain. The experienced workers do most of the preparation, and when novices plan where to store which kind of grain they check with the more experienced workers if possible, to ensure that it is feasible. On one occasion, e.g., one of the novices had booked too many
trucks for the same time slot, and therefore asked one of the experts, “can you help me think...there are four trucks coming in at the same time...how does one handle that?”. The answer was “you can’t let that many come at the same time!”. Then both consulted the phone list to see what the trucks were delivering, and checked the control panel to find out where to store the grain.

![Figure 1. Phone list with notes of expected deliveries. A name is usually crossed off when the delivery is completed.](image)

On arrival at the silo, the farmer or truck driver fills in a form (delivery assurance for type of grain, contract number, etc.). Additional documents with data concerning the delivery, and a strip of bar codes, are printed out by the staff. All the delivery documents are put in a certain order, and then placed on the desk, on one of three colour-and-number coded places (1/green, 2/red, 3/blue) (Figure 24). The colour coding corresponds to the pits for off-loading. Thus documents placed, for instance, on number 3 belong to the grain to be off-loaded into pit number 3. One of the workers collects a sample of the delivered grain and analyses its moisture content, protein level, etc. for classification of the grain (two samples are taken for each delivery, the first directly from the vehicle, before or during off-loading, but before the transportation process is started). The analysis is made in an adjacent room, from where the moisture content percentages are called out, to the people in the control room who will then know which silo to transport the grain to, or if it requires some special handling. One of the workers specifically emphasised that the “numbers must be called out”, which is done continuously during the day, so that all the employees know the current percentages.

The transportation process is started by pressing the appropriate buttons on the control panel. Each pit is connected to a corresponding scale, through
which the process is monitored (Figure 24). As the process is started, the staff member checks the scale to make sure the process starts, that is, the numbers on the scale start changing. As people come and go in the control room, they occasionally check the scales to see how far a process has progressed. The scales are the only gauges in the control room that display whether a process has started, is still in progress, or has stopped. The indicator lights on the control panel only show whether some mechanical process is running, not if any grain is actually being transported or not.

Figure 23. Number-and-colour coded places on the desk on which documents for each delivery are placed. Above the desk, near the ceiling are three scales (black “boxes”), one for each pit for off-loading. Additional equipment connected to the scales lie on the desk (printers, etc.).

The workers also occasionally check the documents. The presence of a strip of bar codes means a sample needs to be taken (Figure 25). This is the second one, which is taken from a pipe inside the facility. The bar codes are used for labelling the samples, but are never referred to as ‘labels’ or something used for ‘labelling’. Instead they are always referred to in terms of ‘taking a sample’, as when a worker picks up the bar codes and says ‘I’ll take a sample’. When a sample has been taken, it is divided into two plastic containers, each of which is labelled (one is stored as a back-up in the facility, and the other one is sent to another company for analysis). The sample itself has no further use in the immediate work processes, but the task of taking the sample is an important part of the overall procedure.
When there are no bar codes on top of the other documents, everyone knows (or assumes) that a sample has been taken. The experienced workers said that “bar codes must always be placed on top of the other documents so that everyone sees them”. This is an implicit ‘rule’, one that has been agreed upon (there is no formal written procedure for it), and all novices are told that bar codes are to be placed on top of the other documents. Sometimes the bar codes are (accidentally) placed beneath the other documents, and the opportunity to take the sample is missed. Such mistakes interrupt the workflow, since the sample must be retrieved through other solutions (this is quite a rare mistake though, and not discussed further here).

![Workers checking the documents of two deliveries, placed on labels one and three on the desk. Bar codes are placed on top of the other documents, which indicate that a sample needs to be taken.](image)

Figure 24. Workers checking the documents of two deliveries, placed on labels one and three on the desk. Bar codes are placed on top of the other documents, which indicate that a sample needs to be taken.

The employees also quite often look on the desk for any documents at all, to check if a delivery is still being handled, because the presence of documents on the desk means the transportation process has not been completed. Sometimes they may also scrutinise the documents to check who is delivering what, if they are contracted farmers, etc. (Figure 26). This is mostly done by the more experienced workers in order to obtain ‘the big picture’ of what is happening. Usually as people come and go in the control room, they check both the scales and the documents to see where they are in the process; the numbers on a scale indicate how much has been conveyed (from which they roughly will know how much remains), and the state of the documents (whether or not there are bar codes) indicate if a sample needs to be taken. Once the transportation process is completed, an additional document that contains the final weight of the delivery, etc. is printed, and all the papers, except a copy for the client, are filed in binders. Clients collect the copy before leaving, or at some later point in time (all
copies left behind are kept in a binder on the desk, from which clients can retrieve their copies themselves).

![Figure 25. A worker checking the documents for a delivery during the conveying process (the roll of paper is a strip of bar codes turned inside out).](image)

Another tool that is used frequently, albeit rather implicitly in the overall work processes, is the whiteboard (Figure 27). In the beginning of the study’s observations, it was rarely used, and thus seemed a rather trivial object. It was used for storing magnetic plaques not in use on the control panel, or for messages like “take out garbage from lunch room”. Over time, however, it became clear that the whiteboard has other more important functions. It is used for information concerning the facility, such as routines to go through, matters that have been checked, and when, dates for major maintenance work, etc. It is also used for information concerning the staff members, e.g., someone’s doctor’s appointment, and for planning the staff work schedule. The employees have flexible working hours which means a schedule, who will work which hours, is agreed upon for a few days, or a week at a time, the exception being the two most experienced workers, of whom one must always be present. To the left on the whiteboard (Figure 27), a typical work schedule with times and initials is displayed. It is written on the whiteboard so that everyone knows who will be working when.
To summarise my observations and impressions from this setting, there were two things that initially caught my attention. Firstly, it was clear that all the tasks were mostly accomplished individually (answering phone calls, start/stop processes, taking samples, etc.). Secondly, there was a visible difference in performance between the workers with much previous experience, and those hired for the season. This is really not surprising, after all, how can beginners know everything (or anything) from the start? However, while all the employees, e.g., used the same tools, the differences between the workers’ experience directed my attention to how the tools were actually used, how they affected the way people used them, and their role in the interactions that took place. Had all the workers been equally experienced, it would likely have been more difficult to explore beneath the surface appearances of tools and interactions, as well as to understand and make sense of the things that took place.

Quite soon it became increasingly apparent that the individually performed tasks always involved more than the individual actually performing the task. Obviously, since all the employees are involved in the overall process of handling the grain, and all the work is related to that process, the general pattern of ‘regular tasks’ emerged quite early. It also became clear over time how even individually performed tasks involve social interactions. Furthermore, the finer details of how tasks, workers, and tools are interrelated, and how things affect one another, emerged during the longer period of observations. In the following section the tasks performed are discussed in relation to some of the theoretical issues discussed in previous chapters.

5.3.3 Social tool use and theoretical issues
In this section I analyse and discuss the use of tools in the control room, in relation to some of the theoretical issues discussed in the background
chapters. When considering the social processes and work tasks of this setting, it is notable that the workers are generally aware of what is happening, and can anticipate the work processes. They know where people are, who is doing what, and so on. At a general level such knowledge and awareness guide the workers’ attention to the duties that need to be done. However, this kind of general knowledge will not be discussed here. Instead I will consider the relations between tools and workers, and how tools are used in and affect the interactions that take place. In the next section we will take a closer look at a new category of artefacts, which is related to experience, and how that affects the use of tools in the control room setting (Section 5.3.3.1). Furthermore, the relationship between agent and environment, and also agent-agent-environment is discussed (5.3.3.2). I will also consider the combination of some tool-related concepts, and its application to this setting (5.3.3.3). The last section (5.3.3.4) examines interactions, mediation, and stigmergy.

5.3.3.1 A new artefact category and experience

As discussed in Chapter 2, there are different proposals for how to categorise tools and artefacts, among them Engeström’s classification of ‘what’, ‘how’, ‘why’, and ‘where-to’ artefacts (cf. Section 2.3.2). Applying this classification to the control room, we recognise that a number of these different kinds of tools, or artefacts (to follow the existing terminology) accord with Engeström’s categories. What-artefacts, that is, external entities used in an activity, include, e.g., documents, scale displays, and the control panel. There are also the two types of secondary artefacts, that is, how- and why-artefacts:

- **How-artefacts** (routines, procedures, etc.) tell the workers how to handle a certain object with a corresponding primary artefact, for instance, routines for conveying grain into the silo tell them how to handle the control panel (primary artefact) to start the conveying process. How-artefacts can be both external and internal, but in the case of conveying grain, there are no external how-artefacts such as written procedures, only (personal) internal ones. Such internal how-artefacts are most clearly expressed in the various ways different workers handle the control panel/machinery; experienced workers’ internalised routines comprise different possible ways of using the control panel/machinery, while the novices’ internalised routines instead are ‘fixed’ and applied on the basis of what is visible on, for instance, the control panel.

- **Why-artefacts** are general types of artefacts (internal, mental explanatory models) that inform the workers why an object of an activity (e.g., the grain) behaves as it does, which justifies the selection of some specific primary artefact. If, for instance, the flow of grain suddenly stops (indicated, e.g., by the numbers on the scale display not changing), a worker constructs an explanatory model of why it has stopped (the model may be externalised in words). Following Engeström’s line of argument (cf. Section 2.4.2), it can be said that the

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61 Parts of this section are included in similar form in Susi (in press).
explanatory model emerges from the worker’s expectations and available data (e.g., type of grain, the control panel’s status, numbers on the scale display). From these ‘first impressions’ (cf. Section 2.4.2), he/she constructs a meaningful pattern, which is subsequently transformed into a hypothesis concerning why the process has stopped, e.g., that there is a break-down in an engine. The hypothesis justifies the selection of certain primary artefacts (e.g., a specific engine and parts of the panel related to it), and the selection of a certain kind of examination and testing, which, in turn, depends on the worker’s knowledge and mastery of their procedures. However, the explanatory models constructed by the workers are not necessarily correct with regard to why an object actually behaves the way it does.

Finally, where-to-artefacts are described as projections into the future, going beyond the explanations and diagnostics of why-artefacts. These are visions of what will follow from, e.g. demanding changes in tools. No such artefacts were identified since there were no plans for any changes in the control room at the time of the study.

In addition to the classification described by Engeström, I have identified an additional category of artefacts, not included in his model. In the previous section, I discussed some of the differences in knowledge between experienced and less experienced workers. Beside the differences, it should be noted that with experience follows knowledge of the past, how things used to be, and changes that have taken place (organisational, tool implements, etc.). Workers who have experienced the changes from manually operated machinery to electrically driven machines operated through a control panel, and/or experienced new technical features being added to the existing machinery, have learned how things relate to each other. They also know how the control panel functions beneath its surface appearance. With this kind of in-depth knowledge, workers know why things appear the way they do, and the functional relationships between machines, and machines and control panel. This kind of knowledge is a crucial element in understanding how the facility works, and being able to operate it smoothly. Since less experienced workers lack this kind of ‘deep’ knowledge, they act instead on the basis of their surface level knowledge of how things work, and thus also encounter many more problems. The kind of experience based knowledge discussed here is an important psychological tool (or artefact), that can be termed a where-from-artefact. Similar to Engeström’s where-to artefacts, where-from artefact go beyond the explanatory or diagnostic ‘why’ function, and they are also close to Wartofsky’s imaginary (tertiary) artefacts; where-from artefacts consist of knowledge constructed from past events, providing a ‘true’ explanation and understanding of why the object of activity behaves the way it does. As such, they are abstracted from their use in productive practice, and have no longer a direct representational function of primary artefacts (cf. Section 2.4.2).

It could be argued that where-from artefacts are similar to why-artefacts, but there are important differences. Even though both of them concern the
matter of ‘why an object behaves the way it does’, why-artefacts are secondary artefacts, while where-from artefacts are tertiary artefacts:

- Why-artefacts are internal and external representations of primary artefacts. They are based on expectations and available data which are transformed into an explanatory model, and workers make use of why-artefacts even without previous experiences (in fact, most of us construct explanatory models, even of things unfamiliar). The role of experience in forming explanatory models is not explicated in Wartofsky’s and Engeström’s concepts of secondary and why-artefacts.

- Where-from artefacts, in contrast, are qualitatively different. Although these are also internal models of why things appear and function the way they do, they are tertiary artefacts, that is, they are imaginary and no longer represent primary artefacts. Where-from artefacts are also based on previous experiences which allow the construction of knowledge that relates previously existing tools with new implements, and an understanding of their functional relationships. Considering the role of experience, one could argue that ‘where-from artefacts’ is just another label for memory. However, these artefacts do not concern memory in general as implied by the term itself. Instead where-from knowledge concerns specifically tool/artefact related experiences/knowledge that affect present tool use. Since where-from artefacts draw on experience, it is plausible to assume that they contribute to current tool use in a manner different than do why-artefacts. Being experience based, they are likely to provide a more ‘correct’ understanding than the explanatory why-artefact, which is based on impressions, available data, etc. Workers construct explanatory models based on available ‘facts’, whether they are experienced or not, and without in-depth knowledge, available data may not lead to a correct understanding or, in the worst case, it might result in mere ‘guess-work’.

In sum, two different types of tertiary artefacts can be distinguished; where-to (vision of the future) and where-from (knowledge of the past) (all the different types of artefacts are summarised in Table 4, with examples from the control room setting). These tertiary artefacts are, of course, psychological tools, rather than material ones. However, where-from artefacts clearly affect the way material tools are handled in the tasks performed in this setting, which also points to the fact that material tools, like any other entity, cannot be considered in isolation; tools and their use can be understood only when considered in relation to their users and the context of their use (cf. Section 2.4.2).
Table 4. A three-level categorisation of artefacts (by Wartofsky, 1979, and Engeström, 1990) expanded with a new type of artefacts.

<table>
<thead>
<tr>
<th>Tertiary artefacts</th>
<th>Where-from artefacts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imaginary artefacts</td>
<td>'Where-to' artefacts</td>
</tr>
<tr>
<td></td>
<td>Vision of future (consequences of new tools in organisation)</td>
</tr>
<tr>
<td>Secondary artefacts</td>
<td>'Why' artefacts</td>
</tr>
<tr>
<td>Internal and external representations of primary artefacts</td>
<td>General type, explanatory model of why object behaves as it does. Justifies selection on certain primary artefact; e.g., flow of grain stops, engine break-down – examine engine</td>
</tr>
<tr>
<td>Primary artefacts</td>
<td>'How' artefacts</td>
</tr>
<tr>
<td>Directly used in production</td>
<td>Specific type that tells how to handle object with corresponding primary artefact; e.g., routine for starting conveying process – control panel</td>
</tr>
<tr>
<td></td>
<td>'What' artefacts</td>
</tr>
<tr>
<td></td>
<td>External physical entities (documents, displays, control panel)</td>
</tr>
</tbody>
</table>

The relation between internal where-from artefacts and external material tools also leads us back to Vygotsky’s distinction between sign and tool. As previously discussed, Vygotsky argued that both of them have a mediating function and they were subsumed under the more general concept of mediated activity (cf. Section 3.2.1). He also argued that even though sign use and tool use can operate independently in young children, the “unity of these systems in the human adult is the very essence of complex human behaviour”. In this thesis language (sign) has been considered as a tool among other tools (cf. Section 1.1.1), but the new artefact category clearly demonstrates that one kind of tool may not be easily understood without the other. However, despite the emphasis on the unity and the ‘mutual linking’ between sign and tool, the general figure depicting their logical relationship does not explicate this mutuality (cf. Figure 4, Section 3.2.1). The use of internal where-from artefacts and the material tools in relation to which they come into use, demonstrates their mutuality in the human adult, and in order to explicate this relation, it can be depicted as seen in Figure 28.

![Mediated activity](image)

**Figure 27.** Sign and tool subsumed under the concept of mediated activity, with an additional link indicating their unity and mutuality.

Where-from artefacts are subjective and vary from one person to another, which is reflected in individual variations and flexibility in the way
experienced workers perform their tasks. This also has some consequences for the novices, who are learning the trade through apprenticeship. Novices acquire their knowledge mainly from verbal explanations and demonstrations, but also by observing how the tools in the control room are used, and through their own practical experience. Considering the subjective nature of the knowledge and performance of the experienced workers, the kind of knowledge acquired by the novices partly depends on who is instructing them in their tasks. Hence, the ‘quality’ of their knowledge (partly) depends on the verbal explanations and demonstrations provided by the experienced workers, as well as the novices own practical experience. Of all the tools and procedures to be learned, the control panel requires the most effort. It is also the one tool in relation to which the ‘master-apprenticeship’ process is most clearly discernible. As discussed previously, errors in handling the control panel are common, and they ensue from both external and internal (mental) factors. While some problems are caused by the control panel’s complex appearance, which provides guidance for certain actions but also leads to errors, other problems result from a lack of knowledge and understanding of the underlying machinery. Although a more comprehensive understanding of the panel emerges with experience gained over time, the kind of knowledge developed by novices may also depend on the quality of the explanations and instructions they are provided with.

This relates to Gal’perin’s method of systematic formation of mental actions and concepts, which was discussed in Chapter 3. In Gal’perin’s view, mental activities (thoughts and images that represent real life situations) emerge as a result of the transition (internalisation) from material to mental activity. He further claims the final product of the internalisation is mental orienting activity, which is used for directing and monitoring further actions. Underlying the orienting activity is the orienting basis that guides the learner in performing an action. According to Gal’perin, the orienting basis includes external, material representations (e.g., instructions) and mental representations\(^{62}\) formed on the basis of the external ones. Since external representations are what provide the learner with an understanding of a specific action, their form is crucial in relation to the kind of understanding the learner acquires. Ideally, according to Gal’perin’s perspective, internalisation and learning should be actively formed through systematic-theoretical external representations (henceforth termed instructions) (cf. Section 3.4.3). Instead of providing learners with ‘finished knowledge’, they should be active explorers under the guidance of a more knowledgeable person. They should also be provided with instructions that lead to theoretical generalisations, which would enable them to orient themselves systematically of the subject under study, and the transfer of knowledge between different domains. Then again, the knowledge required for the tasks in the control room is very domain specific, and knowledge transfer is unnecessary, since there is nothing to transfer it to (except another silo,

\[^{62}\] The term mental representation may be controversial here, but the present discussion is independent of whether mental activity takes the form of, e.g., representations or simulations.
which is still the same domain). Therefore, internalisation and learning could also be formed through systemic-empirical instructions, which would provide the learner with all the necessary conditions and criteria for effective performance from the very beginning. Such instructions, as previously mentioned, lead to more rapid learning with few trials and errors, even though there is no knowledge transfer (cf. Section 3.4.3). However, in the control room, there are no external representations, that is, instructions for using the control panel – the only available scaffolds for learning are verbal explanations and demonstrations, and the workers’ actual manipulation of the panel. The point here is not that there should be material instructions for handling the panel, but that the Gal’perian perspective indicates an important aspect of the apprenticeship process that may be the cause of some of the problems encountered by novices. Assuming the manipulation of external representations underlies the formation of the internal actions, and that no such representations (instructions) are used when learning the control panel, the lack of material instructions could partly explain why novices make many errors and learning how to use the panel takes such a long time (2-4 yrs). Since the learning process is guided and facilitated by experienced workers and their knowledge, the lack of material instructions may make it harder to form correct ‘thoughts and images’ of the panel’s functions.

Differences in amount of experience also lead us to another related issue. In Section 2.4 (artefacts and cognition) Kirsh’s view on intelligent use of space was discussed. This refers to different ways of encoding information in the environment, which may simplify choice and perception. An example from the control room is the desk which has three separately number-and-colour-coded spaces. Each space is used for keeping the documents that relate to deliveries being off-loaded into their corresponding pits. This ensures the workers always know not only the location of the papers for a certain delivery, but also to which delivery they belong, throughout the process. Regarding Kirsh’s discussion on the intelligent use of space, it largely relies on experts’ use of space, and literature in expertise on this matter. It was argued that experts cope without much on-line planning, and that their responsive skills are automatic and unreflective, where actions are intentional but do not result from occasional deliberation. In this setting, however, I found instances where exactly the opposite is true. The phone list, for example, is one way of using space intelligently because it is a part of the overall spatial arrangement where each object has its specific place. The list is always kept in a certain place (by the phone) which gives the list a specific meaning, and it is easily perceived, especially when people are on or about to use the phone. Responding to the list as such (read information, make a note) may be automatic and unreflective, but its true use within the wider frame of ongoing operations, is certainly not.

The phone list is used for allocating delivery times to customers, and for planning the days work. These activities require that several aspects are taken into account; deliveries already noted on the list, the incoming calls, and the status of the silos (which ones are occupied, and with what kind of
grain, as displayed on the control panel), all of which affect the possible ways of maneuvering the transportation process. Planning ahead is a crucial element for ensuring deliveries run smoothly throughout the day, and for keeping the facility operational. This requires a lot of experience (or expert knowledge), not only with regard to handling the control panel or the phone list, but the whole facility. Novices, however, act automatically and without much reflection in the way they often allocate delivery times to the first available time slot on the list. What they typically disregard, is how the expected deliveries relate to other aspects, which may have consequences later on. For instance, it is a mistake to book four grain deliveries in a one hour time slot (as discussed in the previous section), since the off-loading time is longer than that. Too many deliveries of different kinds of grain can also cause problems, such as alterations of the transportation process (the machinery/flow of grain) which may not be possible due to the status of the silos. These problems are not major issues though, since novices soon learn, not only how to correlate the number of deliveries with the time needed for unloading, but also to group the deliveries of different kinds of grain (as far as possible). Nevertheless, the problem of planning ahead remains. Since novices lack deeper knowledge of the facility’s operation, they are unable to relate the information on the phone list to the demands of incoming calls with regard to what can be handled given the status of the silo. The experienced workers, in contrast to novices, have over a long time acquired the skills and knowledge that enable them to relate these different factors and thereby keep the facility running. Also, in contrast to the general assumptions regarding expertise mentioned earlier, it is the expert’s skills and knowledge that allows him to plan on-line, respond reflectively and non-automatically to the different factors. Hence, actions are intentional but in this case they actually result from occurrent deliberation.

Another similar case is the starting up of a process on the control panel. Due to their knowledge, experienced workers can start a process almost automatically and without much reflection, but, when something is amiss their experience (again) allows them to ‘see’ and reflect on the problem. Novices also act automatically and without reflection when they start the process: tracing a line on the control panel and pushing all the buttons along it (whether knowing or not, what they are for). However, often they fail to notice mistakes or other problems although they are visible on the control panel. It is important to note here that even though experience is individual and subjective, and leads to differences in actions, the workers do not act in isolation. Instead, their actions are in relation to others’ actions, and workers with less experience often turn to, and rely on, the knowledge of those with more experience. The help and guidance provided by experienced workers therefore scaffold the actions taken by less experienced workers. Novices also scaffold each other by often discussing, for instance, the meaning of some certain state of the control panel, or how to handle some matter.
In terms of functional tone (cf. Section 3.1.1), all the objects in the control room are neutral, meaningless entities, until a worker enters into a relationship with an object, in which case it becomes a useful meaning-carrier. When a worker enters into a relationship with, e.g., the documents that correlate with each delivery, they are imprinted with a functional tone, which is what makes them real objects. Once a relationship has been formed, objects are imprinted with various meanings, that is, they assume different qualities. On the desk, the documents provide evidence that a process is proceeding, in which case they have acquired a “process-quality”. However, when the same employee takes the bar codes, in order to label a sample, they are instead imprinted with the meaning “label” and acquire a “label-quality”. The change in quality does not depend on the object itself, since it is still the same with unchanged properties. Rather, the change in meaning depends on the worker’s mood. During the first activity he is in a check-up-on-process mood, and during the second he is in a take-a-sample mood. Similarly, the documents assume different meanings, depending on who enters into a relationship with them. The worker who prints out the documents for a delivery is in a handle-incoming-delivery mood. When he places the documents on the desk they assume the meaning ‘process of transportation in progress’, and the bar codes placed on top of them assume the meaning ‘sample needs to be taken’. The employee taking samples is instead in a take-sample mood, and for him the bar codes instead assume the meaning ‘take a sample’. For both of them, the bar codes may also assume the meaning ‘labels for a sample’. Another example relates to the work schedules on the whiteboard. For instance, the symbols “6.00 \rightarrow 14.00 \ UK \ & \ YS” are imprinted with different meanings depending on who enters into a relationship with them. For ‘UK’ and ‘YS’ the symbols assume the meaning ‘I will be working from 6 AM to 14.00’, and for the other workers they assume the meaning ‘UK will work from 6 AM to 14.00’, etc.

An important question here is how the functional tone concept might fit into the context of social interactions. After all, it is focused on individuals and their way of forming a relationship with an object. However, individuals do not act in isolation (cf. Section 3.1.4), and the workers in this case, are all part of a social activity, even though many tasks are performed individually. There are social norms that workers adjust to, as well as social agreements about how tasks should be performed, and tools should be used in this setting (cf. Section 2.4.2). This in itself, of course, does not change an object’s functional tone, since it is ascribed individually, but the social
context may very well be a factor that affects the subject’s mood, which in turn can affect the meaning ascribed to some certain object. In other words, the functional tone imprinted upon an object, may, at least to some extent, depend on the social context in which the imprinting takes place.

In terms of equipment (cf. Section 3.1.2), the way the objects in the control room, and their possible use is perceived, depends on the ongoing activity of the workplace. It is only within the meaningful context of handling the grain that objects (documents, scale displays, etc.) become useful tools, or equipment used in order to achieve a purpose. The usefulness of these objects also lies in the equipmental nexus, the totality of things to which they belong. In the equipmental whole, all things are involved with multiple other things, and they are defined in terms of their different functions. Thus the documents are involved with conveying grain, conveying grain is involved with the control panel, and the panel is involved with the scales, etc. Therefore, the tools used in this setting are not meaningful in themselves. Furthermore, according to this view, it is only when equipment is actually taken up and used that a worker becomes aware of its function and possible use. But understanding equipment also depends on social norms and conventions in the way it is normally used. For example, the control panel is an object that is what it is only when in use, and understanding its possible uses and functions only become clear when it is actually being used, i.e., manipulated, by a worker. Typically, employees do not understand and learn to use the panel merely by watching the other operators, they need to try it themselves. Understanding the panel also depends strongly on the social norms and conventions related to its use (positive or second-hand understanding). It is through the combination of manipulation and the conventions for use that the panel is perceived as a useful tool in the ongoing activity. In contrast, the scale displays, the visible signs of the ongoing processes, are never manipulated so their use and usefulness totally depends on a second-hand understanding of how they are normally used.

In accord with the discussion in Section 3.1.2, the objects in this setting are available to the workers, but they are not aware of (or deliberately think about) how to use a particular object, as long as there are no disturbances. Objects become occurrent only when work is disturbed by, e.g., the malfunction of a piece of equipment or a total break-down (when a piece of equipment is missing). However, while this seems to be the case for the experienced workers, the control panel typically becomes occurrent for the seasonal workers even when there are no malfunctions or other problems. As discussed here, an object is involved with other things, and its usefulness depends on the ongoing activity, manipulation, and social norms. But it seems that the use of some objects also involves the subject’s own knowledge, or experience, or lack thereof. While all the workers know how to use the control panel (trace a line and push the buttons), the experienced ones seem to think little about its use. Seasonal workers, on the other hand, are very aware when using the panel, even when there are no malfunctions or other problems. For example, when they follow the coloured lines they seem not to fully understand how to use the control panel properly (beyond
its surface level properties), as they often hesitate before pushing a button. In this case it is the panel itself, its appearance, and the workers’ lack of knowledge/experience that disturbs them, and makes the object occurrent – not a malfunction or other problem in the object. This also relates to Suchman’s point on the occurrentness of representations (cf. 2.1). According to her, objects tend to be transparent as long as actions proceed smoothly, and it is only when they become problematic that representations occur. A break-down can be caused, e.g., by unfamiliar equipment, in which case the rules and procedures (representations) for handling it (in this case, the panel) are explicated. However, unfamiliarity seems to lessen with time, since the novices soon become familiar enough with the panel to know how to perform certain tasks, but only over an extended time period do they truly learn its proper use. Meanwhile the panel (or representations) continues to occur, even though familiarity with the equipment increases and there are no malfunctions.

In addressing the question of how equipment fits into the context of social interactions, it is clear that this concept is already related to the social context of activity, rather than the subject alone. Firstly, the way objects are perceived depends on the ongoing activity, and it is within the activity that objects become useful equipment. Furthermore, objects are not isolated entities since they are involved with other things, i.e., belong to an equipmental whole. How objects are understood also depends on the social norms and conventions of their use.

In terms of the affordance concept (cf. Section 3.1.3), the objects found in this setting have objective properties that are directly perceived by the workers, ones affording different actions. Within the setting, there are a number of objects that afford different kinds of actions. For example, the documents on the desk afford lifting, holding, carrying, writing, discarding, etc. While the control panel’s buttons afford pushing, and its lines afford tracing, the whiteboard affords writing, and being leaned against, etc. These affordances are invariant and do not change even if a worker’s needs change. Instead it is a matter of perceiving or paying attention (or not) to the existing affordances, and sometimes they are misperceived. A person can fail to perceive what is present or perceive something not present, both of which are cases of misperception. Pushing the wrong button on the panel, for instance, can be caused by misperception. However, this concept is somewhat problematic since affordances (in Gibson’s sense) are objective properties found in the environment, always there regardless of anyone perceiving them or not. Therefore, it is unclear why a particular action is preferred over another. The bar codes, for instance, afford lifting, carrying, or being attached to something, but nothing in the object itself affords the action of taking a sample, and there is no text instructing ‘take a sample’ (which would afford reading the symbols, but not taking a sample anyway). Nevertheless, along with the common use of the affordance concept, most people would probably agree that the bar codes afford (or invite) taking the sample. However, affordances are relative to the
worker who perceives them, and when he perceives manipulability in an object, it is in relation to his hands, to which the object or tool is suited (the bar codes are manipulable, but this still does not explain their relation to the action of taking a sample). Objects like the phone, pens, and documents, for instance, fit both the tasks performed and the worker’s hand. Tools, according to Gibson’s ecological view (cf. Section 3.1.3), are special kinds of detached objects that are graspable, portable, and can be manipulated. An object becomes a tool when it is attached to the body and extends the capacities for perceiving and acting. Thus, from this perspective, objects such as the scale displays would not be tools, but ‘detached objects of the environment’. Regardless of how much they ‘extend the capacities for perceiving and acting’ they never become tools since they are never manipulated or attached to the body. Of course, scale displays are graspable (if one would want to), but they are never grasped because as stationary objects placed near the ceiling, there is no reason to grasp them in the first place. Neither are they portable, and there is nothing on them that can be manipulated. Yet, they are central objects in the work process (or tools according to the tool description in Section 2.6) because they scaffold the workers’ monitoring of transportation processes. The control panel is manipulable, but not graspable, and certainly not portable, and the same is true for the whiteboard, which can be manipulated in the sense that it is ‘write-on-able’ but it is not portable. And none of these objects are ever (even temporarily) attached to the body. Nevertheless they are central tools (again according to the previous description) that extend the capacity of perceiving and acting.

While affordances are objective properties of the environment, perceived affordances are subjective, and related to the subject’s bodily movements. Thus the documents on the desk, or the bar codes, for instance, would display different affordances depending on where in the control a worker is standing, or whether he is moving while looking at them. Nevertheless, bar codes do not have the affordance of taking a sample, and initially not even to label it, since they have to be brought to another part of the facility, where the sample is taken and only then are they used as labels. Besides the affordances of objects, their use is affected by social norms and experiences, as well as the knowledge of the conventional ways of using an object. Thus, the way the objects in this setting are used, is affected by (perceived) affordances, but also by experiences and conventions.

As discussed in Section 2.5, the affordance concept has been extended into sequential and nested affordances, through the inclusion of exploration, which adds a temporal aspect to the affordance concept. According to these concepts, passive observation alone does not reveal all the possible operations of an object, instead they are revealed over time. Sequential affordances are seen, for instance, in the buttons on the control panel. Each button affords putting a finger to it, but the affordance of pushing it is actually not indicated. It is not until the button is exploratorily pushed that the affordance of pushing is revealed. Indeed, there are buttons that cannot be pushed, but their appearance is similar to those that can, and it is only
through exploration that the pushable buttons are revealed. The buttons’ affordances are also sequential since when a button along one of the coloured lines is pushed, and its light turns on, it affords the next button along the same line to be pushed. The indicators thus provide a temporal guidance and structure to the task of starting up a process. Affordances are also grouped in space, that is, they are nested. For example, while the buttons on the control panel afford some kind of handling, no separate part of the panel reveals the possibilities of the whole panel. The affordance of pushing a button is nested within the affordance of tracing a coloured line with several buttons, which is nested within the affordance of starting a certain process, which is nested within the affordance of starting a process to one specific silo, etc. The idea of nested affordances is also somewhat similar to the concept of equipment (cf. above), according to which useful objects always belong to other useful objects, that is, they are involved (nested) with other things. Sequential and nested affordances thus add a more precise level of analysis to the original affordance concept, one with a temporal aspect.

As with the previous concepts, the question of how this particular concept fits into the context of social interactions again rises. Most notably, affordances are objective invariant properties of the environment, and these properties are directly perceived by subjects. Accordingly, all the workers should perceive the same properties, that is, they should detect the same possible actions. But affordances are also perceived subjectively, that is, in relation to the subject’s own body and bodily movements, and those, of course, vary from one individual to another. Similar to the equipment concept, there is also an element of social norms and knowledge of conventional ways of using an object that affect which affordances someone pays attention to. Generally speaking, the control room is an affordance landscape, with a number of different affordances on display (cf. Section 2.5). The affordance concept itself, however, does not explain why some affordances are noted and not others. Therefore, the social aspect may have a more important role than it first seems.

The fourth concept considered is **entry points** (cf. 2.5.2). These are structures or cues that invite entering an information space or a task. In the control room, entry points can be described as cues in the environment that invite a worker to do something. Entry points have different properties, or characteristics, that vary along different dimensions (intrusiveness, richness in metadata, visibility, freshness, importance, relevance). For instance, the documents placed on the desk may invite a worker to closely examine them, since they have a high degree of **intrusiveness**. The documents are intrusive because their specific location on the desk attracts the workers’ visual attention to them. The changing numbers on the scale display (during an ongoing process) have a certain **richness in metadata**. Based on the current numbers, workers know how much of a delivery has already been conveyed, the amount still remaining, and subsequently, how much time it will take before the next delivery can be off-loaded (if someone is waiting for his turn). The strip of bar codes has a high degree of **visibility** since it is placed on top
of the other documents, which increases its chance of being used. When a worker answers a phone call concerning a delivery, he makes use of the phone list, since it has a particular degree of relevance in the current activity. Freshness refers to how recently an entry point has been touched, and ones touched recently are more likely to be used in a current activity. The entry points used in the transportation process are all used continuously, and therefore do not normally vary along this dimension to any larger extent. It is routine, for instance, to check the status of the control panel. The time elapsed since the previous check could, of course, affect the time of the following one. However, workers look at the panel every now and then while in the control room, and they check it as they come and go. The same applies to the scale displays and documents. In this case, then, it is routine and habit, rather than freshness of touch, that affect the entry into these information spaces. It is also notable that when workers check on the status of a process, and do not have to alter anything, they enter these entry points visually, and not by touching them. Perhaps freshness should thus be better described in relation to how recently an entry point has been used rather than touched, since some entry points are not touched at all (again, the scales are never touched).

Many of the entry points in this setting are created by the workers themselves (cf. 2.5.2). Magnetic plaques and hand-written notes attached to the control panel, for instance, are self-created entry points that vary along all the different dimensions, at one time or another. When workers check the panel to see which silo can be used for incoming grain (or when they are planning ahead), the magnetic plaques are highly relevant (useful) for that activity, since they constitute the visible signs of what is stored where. According to the discussion on intelligent use of space (cf. Section 2.5), it could also be expected that the panel plus magnetic plaques would be an instance of intelligent use of space. It was suggested that items could be arranged to simplify perception, e.g., by clustering them into categories that share some similarity, such as colour. Such clustering would lead to less visual searching and reduce the cognitive demands. However, as described previously, the plaques used on the panel have different shapes and colours, without relevance to specific categories. One could argue it would be easier to detect all the plaques for ‘wheat’, or ‘oat’, etc. if each category had one specific colour. On the control panel, however, it is precisely the mix of colours that enables the workers to ‘see’ the different plaques, instead of having to read each one of them. Thus, the space is used intelligently because there is no clustering according to similarity. Other entry points are given rather than created, through an object’s structure, such as the buttons on the control panel. Although not created by the workers, the buttons, when in use, are also self-created entry points because which lights are on/off is the result of the workers’ actions.

This again raises the question of how this concept fits with social interactions. The entry point concept focuses on individuals and their use of environmental structures. As described previously, each individual creates his or her own collection of entry points, and their number varies from one
office occupant to another (cf. Section 2.5.2). Subsequently, such collections are personal and subjective, with differing preferences for the number and type of entry points. When considering this concept in relation to the control room and the workers’ tasks and interactions, there are clearly still a great many entry points. However, in this setting there are no personal, subjective collections of entry points. Instead, there is a common collection of entry points, shared by all the workers (when considering the entry points as a shared collection, the distinction between subjective/objective dimensions is no longer useful; cf. Section 2.5.2). It might be that not all entry points are optimal for each and every worker, or have the form they could have if they had been created individually. However, at a collective level they are ‘good enough’ to function in a way that attracts the workers’ awareness to the tasks requiring attention at some certain point in time.

In summary, these four concepts can be more simply described as follows: equipment refers to objects in relation to a whole chain of other objects and to the context of an activity; affordances are the possible actions for the objects found in this setting, and the control room is an affordance landscape with a number of different affordances on display; objects are imprinted with a functional tone, a certain meaning, by the workers; entry points are the things (typically objects) that invite taking an action, and they vary along a number of different dimensions, which affect the way the workers react to them. Furthermore, equipment and affordances are related to social conventions and norms, and the functional tone imprinted upon an object depends on the subject’s mood, which in a social interactive situation, is most likely affected by other subjects. Entry points, from a social perspective, are common collections of environmental structures, shared by all the workers in the setting. Hence, although these concepts are focused on individuals, they are also useful in the context of subject-subject-object relations.

5.3.3.3 Concepts in combination

The combination of the trigger, placeholder, and entry point concepts (which was made in Section 2.5.2), will be considered in the following paragraphs. Applying the combination of these concepts provides a functional description of the tools used in this setting. One question regarding triggers and placeholders concerns what it is that makes someone notice them in the first place. Triggers, as previously mentioned, are things that prompt a person into action (‘do something’). Placeholders are things that indicate what needs doing, reminders of what to do next. Entry points explain why people take notice of triggers and placeholders. The combination of concepts is shown in Table 5, with examples from the control room setting.

As a reminder of these concepts, a few examples of the different types of triggers and placeholders found in the control room are provided below. For each there are also examples of some entry points, which help explain why triggers and entry points are noticed by the workers.
Triggers can be:

- **Immediate**: when an activity begins immediately after a previous task is completed. Examples:
  - Starting the conveying process when the settings on the panel have been double checked – buttons, lights, and colour lines have a high degree of *intrusiveness* (attract attention), *relevance* (usefulness in current activity), and *importance* (how pressing the activity is).
  - Placing documents on a coded space when the proper pit for off-loading has been chosen – documents have a high degree of *freshness* (how recently they have been used), since they are being printed or already being held while the pit is being chosen.
  - File papers when the process is completed, that is, the final document (with the delivery weight) has been printed – the complete set of documents has a certain degree of *relevance* (usefulness), since they mark the process’ completion at which point they are always filed.

- **Temporal**: actions that happen at regular intervals or after a particular delay. Examples:
  - Regular checks of the phone list, the control panel’s status, and scale displays – these have a degree of *freshness* (how recently they have been used) which affects when they will be used (checked) again.
  - Bringing bar codes to ‘sample station’ when the transportation process has begun and the grain flow has reached the pipe where the sample can be taken. This point of time is integrated with the numbers on the scale display – bar codes have a high degree of *visibility*, meaning they are easy to perceive when placed on the other documents, and they are highly *relevant* (useful) in the activity of taking a sample. The numbers on the scale are both *important* (sampling is a crucial activity) and *relevant*.

- **Sporadic**: when someone remembers that something must be done. Examples:
  - Remembering to file papers, or write something on the whiteboard after having been interrupted. Since these triggers are related to a worker’s internal memory, no entry points are applicable in this case, since they concern properties of external objects (remembering to complete a task could be stimulated by something in the environment, but that would not be a sporadic trigger).

- **External event**: some external event occurs. Examples:
  - A phone call – the phone’s ringing is *intrusive*, which attracts the attention of workers within earshot, and it is *important* since all calls must be answered (clients must be able to reach someone in the facility by phone).
  - Face-to-face request – requests are also *intrusive*, and (in general) one worker talking directly to another does attract the other’s attention.
  - Alarm on the control panel – sounding alarms are *intrusive*, and *relevant* (workers need to know, e.g., when a silo is full). Some alarms are only indicated by a light turning on, and one small light
among all other indicators has a low degree of visibility even though it may be highly important.

- **Environmental cue:** something in the environment that reminds the workers that something needs to be done. The cues are coded explicitly or implicitly.

Examples of *explicit coding*:
- A work schedule on the whiteboard – a current schedule written on the whiteboard has some degree of visibility and triggers the planning of work hours for the next day. The schedule is also important since workers need to know who is working when.
- Hand-written note on the panel referring to one of the silos, e.g. “4/9 20%” – such a note has a certain richness in metadata. While in itself it does not reveal much information for the workers, the note reveals when the grain was stored and the moisture content, which also indicates how and when the grain in that specific silo must be taken care of. Therefore the note also has some importance.

Examples of *implicit coding*:
- Documents or binders not in their proper places – these items have specific spatial locations where they are kept, and when they are not in their proper places they have a certain visibility, and attract the workers’ attention. Noticing these cues can also depend on freshness, when they were last used.

Placeholders are things that remind the workers of what they should do next, and help them to keep track of the progress of the process they are currently in. Many items are both triggers and placeholders, but they differ in their functions. While some examples of placeholders are listed below, I will not repeat all the details of the characteristics (entry points) that enable them to be noticed since their application in this case is very similar to the description above. Instead I will only provide examples of the entry points which apply in which case. The different ways placeholders are stored include:

- **In the workers’ heads:** workers remember what to do next. Examples:
  - To take a sample, or check the status of a process. Since these placeholders are related to a worker’s internal memory, no entry points are applicable in this instance.

- **Explicitly in the environment:** Examples:
  - Documents on the desk – intrusiveness, visibility, relevance.
  - From the numbers on scale displays workers know the current status of a process – richness in metadata, relevance.

- **Implicitly in the environment:** Examples:
  - Whether the coded space on the desk is already empty – visibility, relevance.
  - Whether names on the phone list have already been crossed off – freshness, importance, relevance.
It should be noted that the entry points discussed in the above examples are all (more or less) ones that score high along one or several dimensions. Of course, since entry points vary along the different dimensions (cf. Section 2.5.2) there are also those that may be important, but difficult to notice. The control panel, for instance, is ‘cluttered’ with buttons, colours, hand-written notes, indicator lights that are on or off, and small magnetic plaques in various colours. An indicator light can be difficult to detect among hundreds of others, and a small magnetic plaque blends in well among the other fifty or so. Indicators (light on) at times signalled that something was wrong, but it could go unnoticed for a while. Even though such an indicator is an important trigger (do something), it was not immediately noticed since it has a low degree of, e.g., intrusiveness and visibility. As mentioned previously, such indications mostly drew the attention of the experienced workers, while novices failed to detect them even when looking closely at the panel. It was also obvious that very few problems and break-downs were caused by endogenous (self-created) cognitive tools, such the objects attached to the panel (notes, magnetic plaques) (cf. Section 2.5). Instead, the main source of problems and errors was the control panel itself. The panel is an exogenous tool, created outside the workplace, and then implemented in the facility. As such, it is a fixed entity with a given appearance, comprising a representational layer of indicators, buttons, coloured lines, etc., all of which are related to the underlying machinery. Upon this, additional ‘physical layers of representation’ (Engeström, 1990) have been added by the workers themselves, e.g., magnetic plaques for grains, also handwritten notes referring to conditional states as well as (indirectly) to future tasks and procedures to be performed. Thus the panel is a tool that contains a mix of endogenous and exogenous traits, and it is the externally created structure, provided ready-made to the workers, that causes disturbances.

Another example of a non-salient entry point is the strip of bar codes, if placed beneath the other documents, which has happened on some occasion. Placed under another document, the bar codes have, e.g., no visibility at all, and unless someone actually goes through the documents, the opportunity to take a sample will be missed. In this case, the structure of the documents (their arrangement) is an endogenous cognitive tool that has been socially negotiated, and the problem ensues from deviating from the agreed upon protocol.
Table 5. Combination of concepts, with examples from the control room setting.

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<td>Indicator on panel</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bar codes, plan work schedule</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Docs on desk</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Coded desk space empty yet?</td>
<td></td>
</tr>
<tr>
<td>Freshness</td>
<td>Place docs on coded space</td>
<td>Name on list crossed of yet?</td>
</tr>
<tr>
<td></td>
<td>Check list, panel, scale display</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Docs and binders</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Name on list crossed of yet?</td>
<td></td>
</tr>
<tr>
<td>Importance</td>
<td>Start process on panel</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Scale numbers</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Phone call</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Plan work schedule, hand-written notes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Name on list crossed of yet?</td>
<td></td>
</tr>
<tr>
<td>Relevance</td>
<td>Process complete file document</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bar codes, scale display</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Alarms on control panel</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Docs on desk, scale display</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Coded desk space empty yet?</td>
<td></td>
</tr>
</tbody>
</table>

* abbreviation for documents

As seen in the examples above, there are many triggers that prompt the workers that they need to do something, and placeholders that indicate the current status of a process. The triggers and placeholders are also entry points with certain properties that vary along different dimensions, and when some of the dimensions are salient they stimulate workers into noticing the trigger or placeholder. The above examples also provide instances of given environmental structures as well as exemplifying how the workers themselves have adapted their environment, all of which affect the workers’ behaviours. The environmental structures have been created and adapted to facilitate, not only individual actions, but also processes at a social level. Since the permanence of these structures varies, some are stable while others change. Many of the tools provide a spatially permanent structure because they are never moved, e.g., the scales and the panel. However, although many of the tools are spatially permanent, their status is dynamical. The number-and-colour coded places on the desk, the scales, control panel, and whiteboard are all spatially permanent, but their status endures only for certain periods of time and as one worker makes use of a tool, and thereby alters the workplace structure, other changes follow. It is well known that external structures (or artefacts) coordinate collective activities. Furthermore, distributed cognition approaches, for instance, have shown the inter-dependencies between people and artefacts, and the way information is propagated and transformed in ongoing (collective) activities.
(cf. Chapter 2). An important point here, which is not discussed in distributed approaches, is the way the organisation of collective work processes provides a structure to individual actions that in turn continually produce new triggers and placeholders for one’s own and others’ actions. Roughly speaking, as one worker alters the workplace structure (e.g., by placing documents on a coded place), that action triggers another (starting the transportation process), which triggers another (check the scales), etc. Thus, there is a continuous adaptation of the environment, which guides not only individual workers, but the whole work group as well. Adaptation is also one of the characteristics considered in Baber’s tool use theory, by which ‘augmentation means influence performance’ (Section 2.4.3). However, while Baber describes a one-way adaptation – the manner in which people could (or should) adapt their physical and cognitive activity to accommodate the demands of technology – environment adaptation is clearly a two-way process (cf. Section 2.5. Considering that some tools are supplied externally, their use requires some adaptation by and from the workers, which is exemplified when they create their own tools and structures to facilitate their work.

5.3.3.4 Social interaction, mediation, and stigmergy

Most tasks performed by the workers involve direct or indirect interactions with other employees. Direct interactions are dyadic (face-to-face) or triadic, that is, they are mediated through or involve a material tool. This is common, e.g., when planning ahead or trying to solve a problem, which typically includes the control panel. In Figure 28 we see a triadic interaction, involving two workers and the control panel. In this particular case, an experienced worker (to the left) is explaining to another the possible different ways of using the transportation shafts. In the illustration, both are faced towards the control panel, through which their interaction is mediated (there are other mediating factors as well, such as language, but our focus here is on the material tools). Every now and then, however, the workers turn their heads towards each other, and then they turn their attention to the panel again. Thus, the interaction shifts back and forth between a dyadic and a triadic mode. The worker to the left also uses a screwdriver for pointing, which was observed to be a regular mode of action for this specific employee. The screwdriver itself exemplifies how fluent tool use makes an object itself transparent and unnoticed, and while in use, it is embodied by the worker, extending his effectivity of action (cf. Section 2.3 and 3.1.3). The screwdriver was easily accessible from a pocket of his overall, and appeared in the worker’s hand every now and then while he was involved in a discussion, without anyone paying much attention to it. On a few occasions, however, the screwdriver became stuck in the pocket when he reached for it and its use, and the interaction with others, was disturbed. The screwdriver thus became very occurrent for him, as well as others involved in the discussion, and the fluent interaction shifted to an awareness of the object itself (cf. Section 2.3 and 3.1.2).
Tools can also affect ongoing interactions without the involved participants really being aware of it. For instance, it was observed that while two of the workers were involved in a discussion, the whiteboard caught the attention of one of them. He kept glancing at it for a while, and then steered the conversation into planning the work hours for the coming weekend. What caught his interest was the work schedule already written on the whiteboard, and while they discussed the new one, their interaction was mediated through and scaffolded by what was already there. Both of them kept looking at the whiteboard during the planning, but the new schedule itself was not written down until later that day. On other occasions, interactions were instead disrupted by a tool. One example (video-taped) concerned a worker involved in a discussion, leaning towards the desk, who suddenly stopped talking and looked intently at the control panel. After only a few seconds, he made a motion as if to move towards the panel, but stopped short and leaned back again, saying “what’s this...”. Some five seconds later an alarm sounded. Initially, he was interrupted in the middle of a sentence because he saw something that was not right. Although he could not pinpoint the exact problem until the alarm sounded, he did recognise that there was a problem.

Many interactions are also indirect (asynchronous) and mediated through the use of tools. As discussed in the previous sections, many actions are
prompted by what other workers do. For instance, the placing of delivery related documents on the desk prompts others to start the transportation process, to take a sample, etc. Such actions transform direct social interactions into indirect ones. Other examples of mediated interactions include the use of the whiteboard, the magnetic plaques, and the notes on the control panel. The whiteboard, e.g., is used for information concerning tasks that have been carried out, or ones that need attending. This provides a way of passing on information to everyone without any direct verbal communication. The same applies to the magnetic plaques and handwritten notes (e.g., “silo 16, 18%”), which carry information about the silos and the machinery. Importantly, these tools propagate critical information not only to the workers on the same shift, but also to those on the following one, and when a change is made on the panel, everyone has access to the new information.

Considering the control room in terms of a cognitive system (of workers and tools), there is a number of both internal and external representations (cf. Section 2.2). Internal representations are non-observable, including, for instance, the workers’ explanatory models (why-artefacts), memory, and spoken representations. Spoken representations, like call outs of moisture content percentages (from the adjacent room where samples are handled), provide all workers with information about the incoming grain (where it should be stored, if it requires special handling, etc.) (cf. Section 5.3.2). Since these representations only last while being produced and are not externally recorded, they could easily be missed. On one occasion a discussion broke out concerning these call outs, since the moisture content had changed but no one had been informed of this. It remained unclear whether the call out had in fact been made or not, or if it just had not been overheard by the others. Observable representations include, e.g., messages on the whiteboard, phone lists, and the control panel. Information on the whiteboard is propagated through the system (roughly) as workers read the information and transform it into action. Phone lists with names and approximations of weights are eventually transformed into separate documents containing exact information about each delivery, but also into a wider system of magnetic plaques representing the types of grains stored in the different silos. The representational layer of grains (magnetic plaques) changes constantly, but not very fast (transportation capacity is about 60 tons an hour, thus filling up a 500 ton silo takes 8-9 hours). Another layer of representation is that of transportation shafts (coloured lines) and silos (circles and squares), which is permanent to the extent that changes occur very rarely, if at all. The layer representing the machinery (buttons and indicators for engines, hatches, etc.) is also permanent (changes are very rare), but the state of this representational layer changes often and rapidly. A single activity of starting a process requires that a number of buttons are pushed, and after each pushed button a new representational state ensues. All these different layers provide a scaffold in the form of external memory, guidance of awareness, reminder(s) and shared information. When starting (or stopping) a process, the workers rely on a combination of all these layers. The permanent representation is a constraint for which buttons to push, and
in what order (‘follow a coloured line’), the indicator lights guide when to push the next one (i.e., when the previous light turns on, if it functions as it should, cf. Section 5.3.2), and the magnetic plaques indicate which silo should be used. It is the coordination between such external representations and the workers’ internal ones that operates the system, and as already discussed, when the ‘internal representations’ are undeveloped or incorrect, the cognitive system suffers from interruptions and ‘occurrences’ (of objects and representations, cf. Section 3.1.2).

The control panel is only one of many examples of information propagation, and the different kinds of representations found in this setting. The distribution and sharing of information play an important role in operating the facility smoothly, and although most tasks are carried out individually, they are always related to work already completed, being done or still to do. In a sense, then, considering the workers’ tasks, there is a behavioural paradox, similar to that seen in the cooperative behaviour of social insects (cf. Section 4.2); staff members working on a shift, or those working on different shifts, seem to be cooperating in an organised, coordinated way. At the same time, however, as individuals, they seem to be working on their own rather than as part of any collective behaviour. One way to explain this paradox is in terms of stigmergy. The basic principle in stigmergy, as mentioned previously, states that ‘traces left and modifications made by individuals in their environment may feed back on themselves and others’. ‘Traces’ and ‘modifications’ in the control room are brought on by the workers while performing their tasks. Furthermore, their actions are recorded in the physical environment, as seen in the way they make use of the phone lists, whiteboard, control panel, documents, etc. Thus, the ‘coordination paradox’, and the relation between the individual and social level of activity can be explained, in terms of stigmergy, as indirect interaction where the workers affect the behaviour of themselves and others through the use of tools, which leads to organised coordinated behaviour.

As discussed here, many interactions are triadic, that is, agent-agent-object interactions, in which the interaction is mediated through the object. In such cases, tools facilitate shared understanding, problem solving, planning, etc. As in the administrative unit (cf. Section 5.2), the tools used in the silo also transform social activities into individual processes or actions. At the same time, they also mediate social interactions, thereby maintaining their social nature. Tool mediation facilitates communication and leads to a shared general awareness of the status of different processes and procedures. The tools also provide a shared memory, and propagate information, which supports the workers cooperation and the coordination of work processes. More precisely, coordinative processes, and the relation between individuals and a group of workers can be explained through the principle of stigmergy, meaning that tools not only mediate interactions, but they also provide a means of achieving coordinated collective behaviour at the social level of activity.
5.4 Summary

The two empirical studies described in Sections 5.2 and 5.3 demonstrate that tools indeed do play an important part in social processes. I have also discussed some of their roles in social interactions, which clearly would be arduous to understand without considering the ways tools are used in such processes. To summarise the case studies, I will consider them in relation to the earlier abstracted generalisations of tool use (cf. Section 4.3), and also add some other points. The following aspects are included below: an agent’s activities are always in relation to others, tool mediation, the relationship between subjects and objects, environment adaptation and triggers, tools and their use create and affect future actions, stigmergy, and ‘tooling up’ other agents.

An agent’s activities are always in relation to others. Both empirical studies have shown that even seemingly individual tool use is always in relation to others, and that individual actions (individually performed tasks) are related to the social level of activity (cf. Chapter 3). Therefore, an agent cannot be separated from its environment, which includes, not only material tools, but also other agents. Furthermore, in many cases the tools transform social interactions into individual processes, but at the same time they also mediate the indirect interaction of these processes, and thus maintain their social nature.

Tool mediation. As strongly emphasised by cultural-historical perspectives, activities are always mediated by psychological and material tools (cf. Section 3.2.1). As seen in the second study, novices learn the trade through a process of apprenticeship, where more experienced workers explain and demonstrate how to perform different tasks. Much of the learning is mediated through the material tools, and novices acquire knowledge by observing how the tools in the control room should be used. There are also individual variations and flexibility in the way some tools are employed, as seen, for instance, in the different ways to manoeuvre the control panel. The studies also illustrate that many tool-mediated interactions are direct, as in face-to-face interactions involving a tool (triadic interactions), while others are indirect and asynchronous, and mediated through a tool. Thus, as demonstrated in both studies, tools function as mediators of distributed social interaction and cognition, i.e., they facilitate shared memory, coordination, communication, and the sharing of information. Many tools have the same or similar functions, but the functions vary depending on who is using them, where (spatially) they are used, their functional coupling to other artefacts, the social context, and the ongoing activity.

The relationship between subjects and objects. The different concepts on this matter, discussed in previous sections, can all be applied to the studied settings, each, of course, rendering a different perspective. The functional tone concept provides a more precise description of why objects are used in certain ways; as a staff member ‘enters into a relationship’ with an object, he or she imprints the object with a functional tone, a certain meaning. The meaning ascribed to an object depends on the staff member’s ‘mood’, which
is affected by the activity he or she is involved in. For example, in the silo setting a staff member in a start-the-conveying-process mood may ascribe a certain button on the control panel with the meaning 'starts part of machinery'. Also, considering the social nature of activity, a person’s mood is likely affected by other subjects, which, in turn, affects the functional tone ascribed to an object. The equipment concept places an object in relation to a whole chain of other objects and to the context of an activity. For instance, the tools used in the hospital administrative unit – patient records, document trays, patient lists, table, etc. – are all part of an equipmental whole, and they are used in-order-to (at an over all level) carry out the activity of caring for patients. Considering that equipment is related to an activity, and that all human activity is social, this concept allows us to consider the equipmental whole from a social perspective. In terms of affordances, the studied settings can be considered as affordance landscapes in which all the objects offer a number of different possible actions. The affordances on display are shared by all staff members, since they all occupy the same ‘affordance landscape’, but which affordances someone pays attention to depends on what he or she is doing, and also on social norms among staff members. These different concepts, then, provide different perspectives, not only on the subject-object relationship, which is their original focus, but also in relation to social processes.

**Environment adaptation and triggers.** As illustrated in the empirical studies, staff members and workplaces co-adapt; some environmental structures require that workers adapt to them (e.g., the control panel), but the employees also actively structure and adapt the environments to facilitate their work procedures and tasks. As the workers adapt their environments, they organise and create spatial and temporal collections of ‘stimuli’, which trigger certain actions, and the physical changes that result from one worker’s actions in turn generate further actions in others, etc. Some of the objects in these collections of ‘environmental stimuli’ function not only as triggers, but also as placeholders. A patient record placed in a tray labelled with a doctor’s name triggers the doctor to see the patient. At the same time the patient record, in that specific tray, is a placeholder that indicates to the staff members the current status of the process of treating the patient. Triggers and placeholders are also distinguishable in terms of entry points, i.e., they have certain qualities that affect how someone reacts to them and which actions they trigger, but of course, sometimes workers do not respond to them at all (they may neglect or not notice them). The way things are organised, materially, spatially, and socially (procedures, conventions, etc.), generates patterns that, at an overall level, are robust and coherent enough to maintain work throughout a shift.

**Tools and their use prompt and affect future actions.** Tools and their use have temporal aspects since they are used in a certain way at some particular point of time, they have histories, and they affect future actions. Examples of these aspects include the patient records which have different functions at different points of time (cf. Section 5.2.2), the electronic control panel, which has developed incrementally (cf. Section 5.3.2), and delivery
related documents, which offer different possible future actions (cf. Section 5.3.3.2). In the workplaces discussed in this thesis, the staff members adapt their environments in ways that create future actions, and also affect the kinds of actions that will be undertaken. Some kinds of tool use generate future actions on a short time scale, as in a sequence of pushing buttons when starting a process. The whole task is a sequence of consecutive actions, performed in a short time span. However, the use of the panel also creates other future actions (monitoring scales, stopping processes, etc.). The delivery related documents generate future actions such as taking samples, and filing the documents. In the administrative unit, the patient list(s) create tasks such as receiving patients, taking measures and samples, showing patients to certain consultation rooms, and adding markings by hand. These activities are carried out throughout the day. Thus, tools have a temporal aspect since they create different kinds of possible future actions, and also affect which ones will be performed.

**Stigmergy.** As in the case of the coordination paradox seen in social insects (cf. Section 4.2), a similar ‘coordination paradox’ is seen in human behaviour. Mostly, workers perform their tasks individually, for instance, when a nurse brings a patient record into the administrative unit, or a worker in the silo takes a sample. At the same time, the individual workers cooperate in an organised, coordinated way. The relation between individual action and social level can partly be explained through the principle of stigmergy, that is, indirect interaction through the use of tools. Tool use is a means for controlling one’s own and others’ behaviour, and therefore the use of tools is a means for organising and coordinating the collective behaviour in these workplaces. To regard tool use as a means for ‘controlling’ someone’s behaviour may seem too definite a term, and considering that people may choose not to respond, it is perhaps more suitable to say that tools can affect the behaviour of others. Staff members in the administrative unit turn to the small table for information about pending duties (affecting their own behaviour), and leave information for others (affecting others’ behaviour). Staff members in the silo monitor and respond to the control panel (affect their own behaviour), and leave notes on it (affecting other’s behaviour). While the principle of stigmergy may seem very similar to tool mediation, there is an important difference; tool mediation simply states that an activity is always mediated through a tool, but it does not explain the relation between individual actions and the level of social activity. The principle of stigmergy instead provides a solution to the coordination paradox – it relates individual action and the social level of activity through indirect interaction via the use of tools.

‘**Tooling up**’ other agents. Besides using material tools, staff members also ‘tool up’ others, that is, they use other workers as tools. Even though social tool use has not been discussed to any greater extent, it was clearly observable that workers give each other a helping hand every so often (sometimes without being asked to do so). A novice asking for guidance, e.g., in planning where to store grain, actually ‘tools up’ another person to help perform the task, thereby taking advantage of another worker’s skills and
knowledge. This kind of ‘tooling up’ of others also provides oneself with social scaffolding. A common situation in the silo setting involving ‘tooling up’ others is problem solving; a worker who asks for others’ opinions of a situation, or when someone checks some part of the machinery while another employee stays by the control panel to monitor any changes. Also, when answering incoming phone calls, and someone else is present, it is common that the person taking the call asks the other one to check on the panel where the kind of grain to be delivered is stored, instead of checking him/herself (some customers already ask on the phone in which pit they should unload). Workers also ‘tool up’ others implicitly, through the use of other (material) tools. In the administrative unit, for instance, doctors leave follow-up instructions for samples to be taken, which ‘tools up’ someone else to perform the task.
6. The significance of tools in social activity and cognition

Having discussed some current and historical perspectives, and described the empirical studies, I will in the following paragraphs integrate some theoretical and empirical issues. First, however, in Section 6.1, the concepts of tool and tool use (from Section 2.6) will be considered anew, and their descriptions will be elaborated. Section 6.2 describes the term ‘framework’ and how it is used in the present context, while Section 6.3 focuses on the formulation of a framework regarding the significance of tools in social interactions.

6.1 The concepts of artefact, tool, and tool use

In Section 2.6, tool and tool use were described in the following way: A tool is any object perceived by an agent (or agents) as a tool, and which is used as a means for achieving some purpose (whether the agent is aware of it or not). As such, tools scaffold individual as well as distributed cognition, and extend the capacity of an agent, or agents, to operate within a given situation. This description can now be elaborated with help of some aspects found in chapters 2-5.

Cultural-historical approaches emphasise the mediating role of artefacts, but have to a large extent focused on individuals, mediating tools, and internalisation (cf. Chapter 3). Socio-cultural approaches instead place greater emphasis on social scaffolding, and apprenticeship and learning as a social process. However, as seen in distributed approaches (Section 2.2), and the case studies (Chapter 5), tools mediate not only individual processes, but also distributed social activities. The use of mediating tools also plays an important part in the coordination of social processes, which can (partly) be explained through the principle of stigmergy (cf. Section 4.3 and 5.3.3.4).

From the discussions concerning artefacts and cognition (Section 2.5) and the agent-environment relationship (Sections 3.1), it is clear that there is some confusion about the affordance concept. Furthermore, the way affordances are discussed and used often matches more closely, e.g., the functional tone concept, than it does Gibson’s affordance concept. While affordances are invariant properties found in the environment, providing different action possibilities, the functional tone concept instead emphasises that objects are ascribed with different meanings depending on ‘the subjects prevailing mood’ (cf. Section 2.4.1). Hence, it can be assumed that affordances describe possible actions, but that an object is ascribed with meaning (a functional tone) while in use within a given situation. Furthermore, as a situation unfolds, an object’s meaning may change if the subject’s mood changes. Thus one and the same object may assume different meanings at different points in time.

Commonly, an object is not considered a tool until it is actually picked up and used for some purpose (cf. Section 2.4.2). However, as seen in the previous chapters, not all things used as tools are held in hand while in use.
Examples include space, environmental encodings, wall-mounted displays, and internal cognitive tools. Moreover, tools have a temporal aspect and their affect on behaviour vary from immediate to a later point in time. Hence, what constitutes a tool is not only if and when it is held in hand.

Considering these issues, the description of tools and tool use can now be elaborated as follows:

Artefacts belong to a general, wide category that includes manufactured (modified, etc.) objects in our surroundings. These are the things that are ‘there’, but are not necessarily used in order to achieve something.

A tool, on the other hand, is any object perceived by an agent (or agents) as a tool within an unfolding situation, and used as a mediator between him/herself and the environment. More specifically, a tool is an object ascribed with a meaning of usefulness, in the sense that it can be used to achieve some purpose (whether the agent is aware of it or not).

Through the use of tools cognition is mediated and distributed between individuals and their material and social environments. As such, tools scaffold and mediate individual as well as inter-individual processes, and they extend the bodily and/or cognitive capacities of agents to operate within a given situation.

Tool use also provides a means of coordinating social processes, which relates the individual and social level of activity. The achievement of coordinated social behaviour can be explained through the principle of stigmergy, that is, indirect interaction through the use of tools.

Although this depiction is aimed at describing first and foremost material tools, it leaves open the possibility also to encompass tools other than material ones.

6.2 Framework as a concept
The term ‘framework’ is variously used in different domains and, hence, it has also taken on a variety of meanings. Even a brief look into scientific literature soon reveals that there are numerous examples of frameworks, but a few examples will suffice to clarify how the term is used in this thesis.

The view adopted here is based on Crick and Koch’s (2003) description of framework. In their opinion, a framework combines different ideas that are novel, or ones that have been previously presented by an author him/herself or by others. Although the ideas in themselves may not be new it is, as pointed out by Crick and Koch, the combination of ideas that is original. In their view, a framework is “not a detailed hypothesis or set of hypotheses; rather, it is a suggested point of view for an attack on a scientific problem, often suggesting testable hypotheses” (p. 119). Crick and Koch further explain:
A good framework is one that sounds reasonably plausible relative to available scientific data and that turns out to be largely correct. It is unlikely to be correct in all the details. A framework often contains unstated (and often unrecognized) assumptions, but this is unavoidable. (p. 119)

An example of a framework is Tirassa, Carassa and Geminiani’s (2000) framework for the study of spatial cognition. Their framework consists of a large-scale classification of cognitive architectures, with each class further divided into sub-classes. The classification is analytically based, but intended to be tested empirically. Tirassa et al. consider it likely that empirical evaluations will lead to further refinements of their classification. Another example is Keller’s (2004) instructive framework for comparative primatology. This framework is based on human cognitive ecology, i.e., studies within cultural psychology and anthropology. From an activity theory perspective, she elaborates six generalisations from studies of situated human activity. The generalisations have been applied to findings in non-human primate cognition in order to assess their usability as a situated activity approach for comparative studies on primate cognition. The framework in this case consists of a number of generalisations within one area of research (human activity), applied to another domain (non-human primates), with the intention of finding a common basis applicable in both domains for comparative purposes. The proposed framework is described as ‘instructive’ and Keller calls for further research to assess its utility. While Tirassa et al. and Keller do not provide any definition or description of what they consider to be a framework, both cases are similar to Crick and Koch’s approach in the way they combine different ideas (their own and others’), and they are in accordance with Crick and Koch’s description of what a framework is and is not. My use of the term ‘framework’ is similarly based on a combination of ideas. As the following will reveal, a number of different theoretical issues are combined with the intention of providing a more comprehensive view on the issue of the significance of tools in social interactions. Although most of the ideas have been presented previously, some of them are new, and their combination is novel. Taken together the ideas provide a wider theoretical basis than they do on their own.

6.3 A framework for the significance of tools in social activity

This section presents a framework that describes some of the ways in which tools function in social activities of human agents. As illustrated below (Figure 29; Susi, 2005a; 2005b; 2005c), the present framework draws on knowledge from cultural-historical research, but it should not be considered ‘activity theory research’, but instead a framework regarding a situated cognition perspective on tool use in social interaction. However, the framework could complement activity theory, considering the theory’s emphasis on the importance of mediating tools, and the lack of more elaborate descriptions of the functions of tools, besides their mediating role.

The framework proposed here takes activity theory’s ‘general model of human activity’ (discussed in Section 3.3.3) as a basis. The motivation for choosing this model is that activity theory itself is a framework within which theories can be developed. It also comprises an important, but often ignored,
point typically stressed in situated, distributed, and contextualised approaches: cognitive processes, individuals, tools, etc., cannot be analysed and understood in isolation. Instead, activity theory takes activity as the starting point, and the model contains the basic elements considered to form an activity. The activity model also constitutes a unit of analysis; it includes the elements necessary for a minimal meaningful activity, while, at the same time, providing a guide for what to include in an analysis. Furthermore, the components of an activity are considered in relation to each other. However, given the subject of this thesis, I have chosen to focus on the relation between individuals, their interactions, and tool use (subject-community-tools), in the framework presented here. Therefore, all components have not received equal attention, and, e.g., the ‘rules’ regulating the relationship between subject and community have only been mentioned but not explicitly discussed.

The following list describes the issues included in the framework:

- The model of human activity provides a basis that includes the basic elements of activity, among them individuals, a group of individuals, and mediating tools (cf. Section 3.3)

- The activities of agents are always in relation to others. Although the focus is on tool use in social activity, it is not a matter of tool use and cognition in social processes as opposed to individual tool use and cognition – social and individual processes cannot readily be distinguished as two separate things, and social interaction sometimes takes the form of individual tool related actions (cf. Sections 2.1-2.2, 3.2-3.4, 5.2-5.3)

- Activities are tool mediated and with the aid of tools, in this case material ones, people affect their own as well as others’ behaviour from ‘the outside’. Tool mediation can also be direct, as in face-to-face interactions involving a tool, or it can be indirect, where the (asynchronous) interaction is mediated through or involves a tool. Thus, tools also function as mediators of distributed social interaction and cognition (cf. Sections 2.2, 3.2, 5.2-5.3).

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Figure 29. Graphical depiction of a framework for tool use in social activity.
With regard to the relationship between subjects and objects, the concepts of functional tone, equipment, and affordance, can be applied to describe the relationship from different perspectives. Each concept highlights different aspects (an object’s meaning, objects’ relations and context, possible actions, etc.), and therefore, depending on what we want to explain, each of them can be useful at different times in different situations. These concepts also provide different, complementary perspectives, not only on the subject-object relationship, but also in relation to social processes (cf. Sections 3.1, 5.3.3.2, 5.4).

What objects count as tools depend on their users and situation of use. Within an unfolding situation, a tool is any object perceived by an agent as a tool, and which mediates between him- or herself and the environment. An object becomes a tool when ascribed with a meaning of usefulness, in the sense that it can be used as a tool for achieving some purpose (whether the agent is aware of it or not). Tools scaffold and mediate distributed cognitive processes, and extend the physical and/or cognitive capacities of agents to operate within a given situation (cf. Sections 2.6, 6.1).

Agents adapt their environments by creating structures that facilitate cognition, both in the internal and the distributed sense, even though they may not always be aware of it. Adaptations can be material (objects are used in certain ways), spatial (spatial arrangement of items), and social (norms and agreed upon procedures). Environmental adaptations create triggers that prompt other agents to act, and when adapting the environment, people create structures that facilitate individual as well as social processes (cf. Sections 2.5, 5.2-5.3).

The use of tools prompts future actions, carried out either by the tool using agent him- or herself, or by others. Depending on which tools an agent employs, and how they are used, also affects which future actions will be carried out. The time when such future actions take place spans from immediate to actions carried out at a much later point in time (cf. Sections 2.5, 5.2-5.3).

The principle of stigmergy can be invoked to explain the relation between individual actions and collaborative social activity. Stigmergy states that coordinated behaviour at the social level is achieved through indirect interactions via the use of tools (cf. Sections 4.2, 5.3).

Besides using material tools, agents are also often involved in social tool use, that is, they ‘tool up’ other agents. Agents ‘tool up’ others through direct requests or implicitly through the tools they use, which can prompt another agent to carry out a task (cf. Sections 4.1, 5.4).

In order to gain a descriptive categorisation of the tools used in an activity, they can be distinguished into a three-level categorisation of
tools, or artefacts to follow the conventional use of terms; primary artefacts (what-artefact), secondary artefacts (how- and why artefacts), and tertiary artefacts (where-to and where-from artefacts). While the tools used in an activity are all related to each other, i.e., they all belong to an equipmental whole, these categories allow a more detailed description of the way tools are related (cf. Sections 2.4.2, 5.3.3.1).

- Some of the roles of tools include their function as triggers, placeholders, and entry points. As triggers they indicate something needs doing, and as placeholders they indicate the status of a process, that is, what needs to be done. Tools are also entry points that invite agents to take some action. Entry points vary along different dimensions (they have different characteristics) that affect how agents react to them. The combination of these concepts allows a description that integrates a process view of tools and the characteristics that make agents pay attention to them. While these concepts are applicable to individual tool use, they can also be applied to tool use in the context of social processes, since triggers, placeholders, and entry points are shared by people working together (cf. Sections 2.5, 5.3.3.3, 5.4).

These issues constitute a framework for how to consider tools and some of their roles in social interactions. The ‘triangle’ in figure 29 illustrates the different elements of an activity, and reveal that subject and community are related through tool mediation. The dotted line between the two adds the point that when it comes to coordinated behaviour, and the relation between individual and social level of activity, it can (partly) be explained through stigmergy. Accordingly, coordinated collective behaviour is achieved through indirect tool mediated interaction. This framework also includes an elaboration of the (activity theoretical) element of tools, and places more focus not only on their mediating role, but also on different ways of describing tools. Furthermore the framework explains how agents adapt their environments by making use of various tools to facilitate individual and social cognitive processes, and what it is about these environmental resources that make them function as scaffolds.
7. Conclusions

This chapter summarises the contributions of this thesis, and some possible implications for cognitive science, human-computer interaction (HCI) and computer-supported cooperative work (CSCW), and situated robotics/AI. (Section 7.1). Section 7.2 contains some reflections on the present work, and Section 7.3 identifies some issues for future research.

7.1 Contributions and implications

A major contribution of this thesis is the framework described in Section 6.3, which addresses the significance of tools in social activity and cognition. Theoretically the framework is based on an integration of different aspects from cognitive science, cultural-historical perspectives, different perspectives on the subject-object relationship, and animal tool use. The framework considers interactions between agents and environment, or agent-agent-object interaction, conceptualisations regarding the function(s) of tools, and different ways that agents adapt their environments to facilitate individual and social processes (Susi, 2005; Susi, Lindblom & Ziemke, 2003). It also includes stigmergy (tool mediated indirect interactions) as a mechanism that relates individual and social levels of activity (Susi & Ziemke, 2001). All the issues included in the framework have also been illustrated empirically in the case studies (cf. Chapter 5; Rambusch, Susi & Ziemke, 2004; Susi, 2005c, in press). To summarise the issues included in the framework (described in Section 6.3), they state, in short, the following:

- The model of human activity provides as basis that includes the basic elements of activity, among them individuals, a group of individuals, and mediating tools.

- Tool use in social activity includes a consideration of both individuals and the larger group of individuals involved in the activity, since individual actions are always in relation to others, and social interaction sometimes takes the form of individual tool related action.

- Activities are mediated by tools, and they mediate individual actions as well as direct and indirect social interactions. Mediating tools also provides a means for affecting one’s own and others’ behaviour from ‘the outside’.

- The relationship between subjects and objects can be viewed in terms of the equipment, functional tone, and affordance concepts, depending on what we want to understand and explain. Each perspective highlights different aspects and as such they provide complementary views on the subject-object relationship.

- Which objects count as tools depend on their users and situation of use; objects perceived as useful within an unfolding situation become tools in that very situation.
• Agents actively adapt their environments by creating (material, spatial, and social) structures that facilitate individual and social processes.

• Tool use prompts and affects future actions, in a short and/or long term.

• The use of tools facilitates indirect interactions, and contributes to coordinated ‘stigmergic’ behaviour at the social level of activity.

• In addition to material tools, agents also ‘tool up’ other agents.

• The three-level artefact categorisation provides a relational description of the tools involved in an activity.

• Considering tools in terms of triggers, placeholders, and entry points, provides a description of tools that includes a process view as well as characteristics that affect how agents react to the tools.

Regarding tools and their use, I have provided a description of tools to account for what a tool is, and what makes an object a tool (cf. Sections 2.6, 6.1). The description focuses on external material tools, but it also allows the possibility of including tools other than material ones. For instance, the previously identified ‘where-from’ artefact (knowledge of why an object functions and appears the way it does; cf. Section 5.3.3.1), fits the description (cf. Section 7.3). Also, in contrast to many existing agent- or object-centred definitions, it provides a situated perspective on tools and tool use. In sum, which objects count as tools depends on the user him/herself and the unfolding situation within which some objects become tools.

On the matter of tools and their functions, there are two novel contributions: a new artefact category (Section 5.3.3.1) and a combination of concepts (5.3.3.3). Firstly, the artefact categorisation formulated by Engeström (based on Wartofsky’s categorisation), describes internal and external artefacts, and their relations within an activity. The second empirical study revealed a new category, which I have termed where-from artefacts (following the existing terminology) (Susi, in press). A where-from artefact is knowledge of the past, that is, knowledge of why things function or appear the way they do. As such, they are internal artefacts, but they play an important role when it comes to understanding use of external tools. This also points to the fact that material tools need to be considered in relation to other aspects of cognition and tool use. Subsequently, this new category extends the existing categorisation by adding a dimension that contributes to understanding why someone handles an external object in a certain way. Secondly, I have combined the concepts of triggers, placeholders, and entry points (Sections 2.5.1-2.5.2) (Susi, 2005c). In contrast to Kirsh’s view (cf. Section 2.5.2), I do not consider triggers and placeholders as ‘surface structures’, or entry points as the abstraction that provides insight into the deep structure of workplaces. Instead, the combination of these concepts provides more insight into that deep structure, than either does on its own. The
combination of these concepts provides a means for describing tools from a temporal and characteristics perspective. It is also a means for describing the functional role(s) of tools on a level of abstraction that allows us to go beyond mere enumerations of the kinds of things found in one or another setting. Furthermore, in contrast to these concepts’ original focus on individuals, I have applied their combination to a social context (Section 5.3.3).

Different concepts on the **relationship between subjects and objects** have been discussed, and also applied to the second empirical study, which shows that they are all useful, but provide different perspectives and explanations (cf. Sections 3.1, 5.3.3.2, 5.4, 6.3). While it is a given that different concepts provide different explanations, an important point here is that the various conceptions should be applied more carefully. Commonly they are used quite interchangeably and phenomena that might be better explained in other terms, are often conflated under the term of ‘affordances’. For instance, what is described as misperceived affordances may be a question of different users attributing an object with different functional tones (Susi & Ziemke, 2005).

The **empirical studies** reported in this thesis have contributed to the framework by illustrating some of the theoretical issues discussed in the background chapters (Rambusch, Susi & Ziemke, 2004; Susi, 2005c), and (the second study) also revealed unforeseen aspects of tool use. The studies also consider tool use from a social interaction perspective (tool use in relation to social cognition, and tool use in social interactions; Sections 5.2-5.3), instead of focusing on individual cognition. The studies are also valuable in themselves in that they provide some insight into the important roles of tools in those particular studied settings. Also, the silo study should be of general interest because it was carried out in a domain where cognition research is not common, and which probably is unknown to most cognitive science researchers. In that sense it is a useful complement to other cooperative workplace studies that have emphasised the role of tools in cooperative (and other) processes.

Besides these contributions, the current work has some **implications**. From a **situated cognition** perspective, this thesis represents a novel integration of ideas from different perspectives, and different tool/artefact concepts have been elaborated to provide a more comprehensive view on how to consider these terms, and the role of tools in situated activities. Hence, the present work can contribute to further knowledge regarding the situated nature of human activities, and the way cognition is distributed between agents and their environments. Furthermore, it complements previous situated cognition research and may provide a basis for how to approach the issue of social interactions, cognition, and tool use from a situated perspective (cf. Section 7.3).

Situated cognition approaches are also gaining influence in other areas concerned with interactions and (technological) tool use, such as HCI and CSCW. In the introductory chapter I mentioned the ‘socio-technical gap’ (i.e.,
a discrepancy between what is technically feasible and what is socially desirable. Systems aimed at facilitating cooperative work often do not blend in as a natural part of such work processes, partly due to a lack of understanding of the ways people make use of technology and other tools, and how they affect interactions between people. Thus, while much has been achieved by an ever improving technology, and social aspects of human cooperative work have come to be better understood, systems aimed at supporting cooperative work do not always fulfil their intended role as supporting devices and people invent their own ways of using them to make them fit their work tasks. A consideration of technological and other tools from a situated perspective, as presented in the present framework, can contribute to further understanding how agents use (or not) technology. Such an understanding may in turn reveal considerations regarding the design of supportive technology.

Artificial and robotics research is faced with a similar situation of limited understanding of the role of the environment (Ziemke, Bergfeldt, Buason, Susi & Svensson, 2004). Robots/AI systems hardly manage tool use at all and attempts to model social processes, including the use of material artefacts are scarce (for attempts to model human behaviour that include the use of artefacts, see, e.g., Agre, 1995; Hammond, et al., 1995; Ugolini & Parisi, 1999; see also St. Amant & Wood, 2005). Moreover, while there is plenty of research on robots adapting to their environments, there is very little work on robots adapting the environments to their own needs and ‘cognitive’ limitations (cf. Buason, Bergfeldt & Ziemke, 2005). By now we know that humans actively structure their world in a way that sufficient cognitive scaffolding (e.g., in the form of affordances, functional tones, entry points, etc.) is available to support meaningful action sequences, rather than just individual reactions. This is of particular interest in collaborative work environments, where social interactions and work coordination is distributed and often mediated by the physical environment. However, in current artificial and robotics research the capacity to modify the physical environment in order to create such ‘cognitive’ scaffolding for individual and distributed cognitive processes is still almost completely lacking (Agre, 1995; Ziemke et al., 2004). Therefore, further knowledge on tool use and environment interactions in cognitive science can also contribute to artificial and robotics research (and vice versa). As discussed in previous sections, the matter of how to conceptualise the relationship between agent and environment is a relevant question when it comes to understanding what the properties are that make objects and their functionality easily accessible to human subjects. This relationship is also an important issue for the design of artificial subjects like robots, and how they can meaningfully perceive their environment and adapt it according to their needs (cf. Susi & Ziemke, 2005).

7.2 Reflections
This section contains some reflections on this thesis, the framework, and the value, or trustworthiness, of the presented work.
In the introductory chapter it was said that this thesis aims to put some pieces of the puzzle of social activity into new constellations as well as to add some missing pieces to it. This has lead to the formulation of a framework regarding tool use in social interaction. This work has also shown, foremost through the empirical studies, how even seemingly individual activities in fact are social activities, that social activities sometimes take the form of individual activities, and the way these activities are tool-mediated.

Regarding the empirical studies presented in this thesis, both cases fulfil the purpose of illustrating theoretical issues, but there are differences as to what can be claimed regarding their results and conclusions. To begin with, the first study, in the children’s admission unit, has not been discussed here in as much detail as the second study, because the empirical part was not carried out by me personally. Also, at the time of that study, only limited time could be spent on data collection, and for reasons of confidentiality the video taped material involving patients and staff was accessible only during a limited time period. This, of course, allows only the most obvious and common instances of tool use to be captured, which then provides a basic understanding of the complexities of that setting. Nevertheless, even with this limitation, the study provided valuable insights, and illustrated some aspects of the relation between individuals and tools in a social context. It could be argued that the present work cannot rely on or draw any strong conclusions from the first case study and, while this is true, I instead made much more use of the second study, which was completely carried out by myself. However, the time spent on data collection in the second study was also limited due to the harvest season only lasting a certain time and because I chose to be present only during shifts with workers who had agreed to participate in the study. However, considering that both studies were aimed to be illustrative cases, I do not consider the time spent on data collection a serious problem. Instead, despite this limitation, unforeseen findings did emerge, and the empirically based claims of this work rely on the control room study.

The framework presented in Section 6.3 does not claim to be the ‘Holy Grail’ that Clark requests (cf. Chapter 1), neither does it claim to provide a precise answer or solution to the exact roles of tools, or how they affect interactions and cognition. However, as discussed in Section 6.2 regarding the framework concept as such, a framework should ‘sound reasonably plausible relative to available scientific data’, even though it is ‘unlikely to be correct in all the details’. Given the reviewed literature and the data from the empirical studies, the framework is, I believe, reasonably plausible, but naturally, as for any framework, the details need further elaboration and empirical testing. In its current form, it includes a number of important issues to consider regarding the social side of tool use, and it provides a basis for further research (further discussed in the next section).

Considering the description of tools and tool use adopted in this thesis, one might get the impression that everything is a tool, and if so, what is the point in describing them as tools at all? After all, would not an all-encompassing
description be quite meaningless? The obvious answer is ‘yes’, but what objects should count as tools ‘depends’; it depends on the unfolding situation, and objects that are found useful within a certain situation become tools in that very situation while in use. Moreover, a tool description centering around the situation at hand and the usefulness of objects to achieve something, escapes, for instance, the border line cases encountered by Beck’s (1980) renown tool definition when applied to human behaviour (cf. Section 2.4.2). According to Beck, a tool must not be attached to the body, it must be held or carried when in use, and it should have no reference to cognitive processes. However, as discussed in previous chapters, hands may be used as tools, and some tools are not held or carried when in use, and certainly, to consider them apart from cognition would not contribute to understanding human tool behaviour (cf. Sections 2.5, 5.2-5.3).

It might also be worth noting that tools and tool behaviour vary along a number of different dimensions, and are therefore not always fully describable in terms of either/or. A tool, for instance, is not necessarily this or that kind of a tool, and it does not necessarily mediate either individual or social activities. Figure 31 describes some general such dimensions of variation. Although the graphical depiction is static, the dimensions vary along a continuum, with their dynamicism indicated by the two-way arrows.

**Dimensions of tools and tool use**

<table>
<thead>
<tr>
<th>People involved</th>
<th>Individual</th>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kind of tool</td>
<td>Elementary</td>
<td>Complex</td>
</tr>
<tr>
<td>Kind of tool use</td>
<td>Internally oriented</td>
<td>Externally oriented</td>
</tr>
<tr>
<td>Tool using skills</td>
<td>Novice</td>
<td>Expert</td>
</tr>
<tr>
<td>Tool’s affect on behaviour</td>
<td>Short term</td>
<td>Long term</td>
</tr>
<tr>
<td>Environment adaptation</td>
<td>Adapt to environment</td>
<td>Adapt the environment</td>
</tr>
<tr>
<td>Individual performance</td>
<td>Mediation</td>
<td>Coordination/stigmergy</td>
</tr>
</tbody>
</table>

**Figure 30.** Different dimensions of tools and tool use.
- **People involved**: The number of people involved in tool use differs from one situation to another; activities may be individual or social, or shift between the two. Even individually performed actions are always in relation to social activities, and social activities may be individually performed. Also, the number of people involved may vary from one moment to another while a task is being carried out (cf. Chapter 5).

- **Kind of tool**: The tools discussed in this thesis range from simple to more advanced ones; they vary in their degree of complexity, varying from elementary to more complex tools. Elementary tools are the ones we (intuitively) would consider ‘simple’ (from a human perspective) such as a traces left in the environment, a stick, or a knot tied as a reminder. Complex tools instead comprise, for instance, documents (containing procedures, instructions, etc.), computers, and other technological systems. Of course, these are different kinds of tools, but when considering them in terms of, for instance, their functions within the larger frame of activity in which they are used, they may be more usefully considered in terms of difference in degree rather than difference in kind (cf. Section 4.1); several different kinds of tools may, for instance, prompt someone to take action, but some tools fulfil that function better than others (cf. Chapter 5).

- **Kind of tool use**: Tools also differ in their orientation, i.e., whether they are externally or internally oriented. Material tools are externally oriented, leading to changes in the object of activity. Psychological tools (signs) instead are internally oriented and provide a means for mastering oneself, but they do not change anything in the object of a psychological operation (cf. Section 3.2). However, psychological tools can also be externally oriented in the sense that they are sometimes used for ‘social purposes’, affecting the behaviour of others. Similarly, material tools can be internally oriented in the sense that they affect the user’s own cognition and behaviour, providing external means for ‘mastering oneself’.

- **Tool using skills**: Tool use is also affected by the users’ experiences and skills (cf. Section 5.3). With little or no previous experience of a work setting, its tasks and procedures, novices typically cannot handle the tools in an efficient manner as do experienced workers.

- **A tool’s affect on behaviour**: The time scale for a tool’s affect on behaviour varies. Some tools only affect peoples’ behaviour while they are being used, but others do so on a longer time scale. For instance, tools used for planning affect and prompt future actions, while the tools used for starting a machine only affect someone’s behaviour while the machine is being started (cf. Section 5.3).

- **Environment adaptation**: Another dimension of tools concerns whether, or to what degree, people adapt their environments by creating new tools or comply with existing ones. While people are good
at making use of existing tools, they also adapt their environments (create new tools and structures, develop strategies, etc.) to facilitate individual as well as social processes (cf. Sections 5.2-5.3).

- **Mediation**: Tools function as mediators of individual as well as social activities, but their role oscillates between individually oriented mediation, and mediation among a group of people. Tools that mediate social processes, and allow people to interact indirectly through the tools, contribute to stigmergic (coordinated) behaviour.

Possibly these (and other) dimensions can be combined in different constellations to provide a tool-box for analysing tool use. Different combinations will allow us to consider different aspects of tool use, which is, metaphorically speaking, like viewing a crystal from different angles (cf. Section 5.1.3). Figure 32, for instance, contains the combination 'people involved' (vertical axis) and 'kind of tool' (horizontal axis), which considers the number of people involved in an activity and the degree of complexity in the tools used. Assuming that an activity centres, or should centre, around the intersection of the two dimensions, a consideration of the tools involved on the basis of the combined dimensions, could reveal which tools are central to the activity and which are peripheral. As an example, a complex tool such as a written procedure for a specific task (e.g., how to analyse a grain sample) may support the individual worker, but leave its relation to the wider frame of activity unspecified, and provide no support for the overall activity of a group of workers. A tool supporting both the individual as well as a group of workers does not necessarily have to be complex – even a simple one can do that, e.g., the bar codes used for labeling samples. As already discussed, the bar codes prompt individual workers to take action, while also indicating to the whole group of workers where in the process they are. Such tools oscillate between the poles ‘individual’ and ‘group’, and are more central to the activity than, for instance, an individual or group oriented one.

**Figure 31.** Combination of the dimensions 'people involved' and 'kind of tool'.
Another issue concerns how to evaluate the present work. One possibility is to evaluate it in terms of the criteria for trustworthiness suggested by Lincoln and Guba (1985), which include credibility (triangulation, peer debriefing, and member checks), transferability, dependability, and confirmability (cf. Section 5.1.2):

- Regarding credibility, I have triangulated different theoretical perspectives (Chapters 2-4), techniques for data collection (interviews, observations, video recording) and data sources (field notes, video tapes, auditorial recordings). As for peer debriefing, the ideas and contents of this thesis have been discussed with other researchers, and parts of this thesis are also based on a number of peer reviewed publications (Rambusch, Susi & Ziemke, 2004; Susi, 2005, in press; Susi & Lindblom, 2005; Susi & Ziemke, 2001, 2005; Susi, Lindblom & Ziemke, 2003; Ziemke, Bergfeldt, Buason, Susi & Svensson, 2004). Member checks were made with participants in both empirical studies, who verified that tasks, processes, etc., were correctly understood.

- To what degree the results are transferable is not really for me to judge. In the case of transferability, as mentioned previously, the burden of proof falls on the person wanting to make a transfer. My role, with regard to transferability, is to provide descriptive data that allows a judgement of contextual similarity. Descriptive data on the studied settings has been provided in Chapter 5. However, considering the abstraction level of the framework, it should be independent of, for instance, exactly what objects are found in a setting or which agents are involved in some certain task.

- Considering dependability, by definition in situ studies can never be predicted or repeated since they unfold under various circumstances and in different contexts. Context as such is not some specific ‘place’ or ‘situation’ to be interpreted; it emerges in the ongoing interactions with the environment. Therefore, instead of considering predictions etc., the inquirer is responsible for accounting for the context of the research; changes that take place during the study and how they affect the study. In Section 5.1, I have detailed the relevant methodological issues for approaching a naturalistic setting, and Sections 5.2 and 5.3 describe the contextual aspects of the empirical studies.

- The confirmability of results (findings and conclusions) can be evaluated by the extent to which they are confirmable by the data. Ideally, all collected data should be made available, but that is not possible for ethical reasons (e.g., patient confidentiality). Instead, in Chapter 5, I provide detailed descriptions of the settings, work processes, and the kind of data collected. For the control room study, I also provide examples of field notes and transcriptions (see Appendix), and include quotes from the participants. Furthermore, workplace descriptions, procedures, etc., have been confirmed by the participants.
Finally, I would like to turn to Patton (2002), who says there are some 'central elements of a good description', captured by the poet Kipling that reads: "I keep six honest serving men. They taught me all I knew: Their names are What and Why and When and How and Where and Who." (ibid., p. 276). When considering the trustworthiness of this work, the descriptions of findings and conclusions, I hope each of the six have received sufficient attention.

### 7.3 Future research

This section briefly considers a few issues for future work, which include further elaboration of the framework, and the role of embodiment in tool use and social interaction.

The combination of the trigger, placeholder, and entry point concepts (cf. Sections 2.5.2 and 5.3.3.3) needs further elaboration. The application of these concepts to the studied settings shows that they can be usefully combined, and as such they could, for instance, contribute to elaborating the method of trigger analysis (Dix et al., 2004; cf. Section 2.5.1). What is lacking, however, when combining these concepts in a matrix, is how to represent just how salient an entry point is (cf. Section 5.3.3.3). In its present form, the table only suggests, for example, that a trigger is noticed only when it scores high on some dimension, and that it is not regarded when not salient. What is needed therefore is a more detailed way of describing the salience of the different dimensions. Perhaps a matrix is not the right representational mode at all, but it is the task of future research to find a proper way of representing these concepts, as well as their salience. It is also possible that there are yet unknown types of triggers and placeholders, and more entry point dimensions awaiting revelation.

The briefly summarised framework in Section 7.1 (which includes the combination above), incorporates a number of important issues to consider with regard to the social aspect of activities and tool use. These issues can be further elaborated into more precise detail. Furthermore, the issues could easily be converted into questions which provides the possibility of developing, for example, a methodological approach concerned with what questions to ask and issues to consider in studies of situated activity. The combination of different tool and tool use dimensions (cf. Section 7.2) could also contribute to such a methodological approach.

With regard to the model of human activity that underlies the framework, only some of its elements have been considered in any depth. Future research should include an examination of the remaining elements (object, rules, division of labour) to discover how they position within the present framework. If they fail to fit properly, perhaps the underlying model needs to be changed.

Another question that needs further attention concerns the origins of tool behaviour. As discussed in this thesis, people are skilled in exploiting tools
for cognitive purposes, and in developing cognitive strategies, but why are humans such proficient tool users, and how did the need for tool use originate? Or, as Clark (1999, p. 350) phrases it, “insofar as we depend heavily on cultural artifacts...what should we say about their origins?...just how did dumb brains create such a smart world?”. Of course, the question is not novel, but it still seems to lack an explanatory answer. Perhaps the works of Vygotsky and his colleagues can contribute to finding an answer. They argued that explanations of mental processes require examination of their origins and development (cf. Chapter 3). They also emphasised the importance of, for instance, object manipulation, internalisation, and social scaffolding in development, and possibly these matters can help explaining the origin of skilled human tool use.

The relation between psychological and material tools also needs further in-depth examination. In their original description, they are internally and externally oriented, respectively. However, they are also mutually interrelated (cf. Sections 3.2.1, 5.3.3.1), which means their distinction is not that clear cut. Language, for example, is both internally and externally oriented; “words and text are external objects that we can encounter and manipulate and key instruments of inner, abstract reason” (Clark, 1999, p. 350). Similarly, a material tool, although externally oriented, can feed back on its user thereby changing his/her psychological processes. Thus, their relationship should be examined and explicated in more detail.

Another important aspect of tool use in social activity and cognition is embodiment, which is important with regard to both using a tool and social interaction. Nevertheless, just as the role of tools in social interaction has largely been neglected, so too has the role of embodiment. However, embodiment is receiving increasing interest from contemporary scholars, who emphasise that body and mind are not two separate things, but rather two ways of describing the same process, i.e., the activity of the human organism in its environment (Clark, 1997; Lindblom & Ziemke, in press; Rogoff, 2003). As mentioned in passing, tool use emerges out of object manipulation, and cognitive processes depend on experiences from having a body with particular sensorimotor capabilities that interact with the surrounding world. Thus, bodies, tools, and social interactions are tightly and dynamically interrelated, and an important area of future research could be their integration. Such an integration is also called for in areas such as human-computer interaction and computer-supported cooperative work. Dourish (2001), for instance, proposes an embodied interaction approach, because “we need new ways of interacting with computers, ways that are better tuned to our needs and abilities” (ibid., p. 1). Guidance for the integration of embodiment, tools, and social interaction may be provided by work such as Robertson’s (2000) taxonomy of embodied actions, which includes, for example, individual and group activities as well as physical objects. Progress regarding such an integration may also contribute to bridging the socio-technical gap mentioned in the introductory chapter. Subsequently, there is a need to develop an alternative explanation of human cognition and communication, one that does not overlook the bodily
and artefactual aspects of social interaction and cognition (cf. Susi & Lindblom, 2005).

Finally, now that some different aspects of ‘the puzzle of social activity’ have been discussed and we have seen the significance of tools in cognition and cooperation, we may remind ourselves of the words of Provine (1996), in the introductory epigraph, and acknowledge that we indeed “should resist neglecting or trivializing the commonplace”, that there are “rewards for approaching nature with a naive curiosity and attempting to see the familiar in new ways” (p. 46). However, this is only the beginning, and future research will certainly reveal further aspects of tool use in social interactions. After all, as expressed by Rogoff (2003, p. 369), there is always more to learn...
References


Gelman, S.A. & Bloom, P. (2000) Young children are sensitive to how an object was created when deciding what to name it. *Cognition, 76*, 91-103.


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Appendix

Figure 32. Notes taken at the beginning of the study, describing what takes place in the control room upon delivery of grain.

Figure 33. A note of things written on the whiteboard by staff members, such as working schedule and things that need to be taken care of (‘checklist for oil levels not approved’, ‘dust on 4th floor’, etc).
Figure 34. Notes taken during observation, on the process of taking a grain sample.
Figure 35. Transcript of video tape. In this case three workers are solving a problem caused by technical problems. The workers’ comments are in quotation marks, numbers to the left refer to the time on the video tape, and angle brackets contain my own comments.