

The coordination of cooperative work through artifacts

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Master Thesis

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‘Stupidity consists in wanting to reach conclusions. We are a thread, and we want to know the whole cloth ... what mind worthy of a name, beginning with Homer, ever reached a conclusion? Let’s accept the picture. That’s how things are. So be it ...’

(Gustave Flaubert)

Abstract

Researchers in the field of Computer Supported Cooperative Work (CSCW) have increasingly come to realize that artifacts play an important role in the coordination of cooperative work. This master thesis is an attempt to make an inquiry into the nature of artifacts and the coordinative practices employing them. Based on concepts of process, practice, materiality, context and the temporal nature of meaning, an attempted is made to develop an understanding of the coordinative roles of artifacts that take into consideration the complex interplay of coordinative practices and the material forms of artifacts.

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Problem

How is cooperative work coordinated through artifacts?

Introduction

As an introduction to this thesis, I will try to give an overview of the field of CSCW, in order to contextualize the work ahead. We shall have a look at some central aspects of CSCW i.e. key concepts and research agendas, and we shall have a first impression of the importance of artifacts in cooperative work.

The field of Computer Supported Cooperative Work, or CSCW, appears to have been established as a research field in its own right over the last decade (Schmidt and Bannon 1992, p.8). CSCW can be described as a design oriented research area, oriented towards the design of computer systems for the support of a certain kind of work – namely cooperative work. In other words CSCW can be described as a research and design field in search of an understanding of cooperative work, with the purpose of informing the design of computer based technologies for the support of cooperative work (Schmidt and Bannon 1992, p.11). Thus CSCW can primarily be described as a design oriented research field.

The acronym CSCW can, for the purpose of clarity, be split into CS (computer support) and CW (cooperative work). For now we shall have a closer look at cooperative work and associated concepts.

Cooperative work is work, and all work is immediately social. Nothing that we humans do is done outside of a social context and all our practices are therefore socially and culturally mediated (Huges, Randall, Shapiro 1991). That does not imply however that all work is cooperative work, as the concept of cooperative work is

understood within CSCW. Work is understood as cooperative when the involved actors are mutually interdependent in their work and therefore are required to cooperate in order to get the work done (Schmidt & Bannon 1992). The notion of interdependence is key here. On account of these interdependencies, all cooperative work practices entail activities that are aimed, in a sense, not so much at the work itself, but at the cooperation – typically: who does what when. This meta-work is conceptualised as *articulation work*. Cooperative work is articulated in the sense that actors involved in cooperative work must share, allocate, coordinate, mesh, interrelate etc. their distributed individual activities (Schmidt & Bannon 1992, p.14). Articulation work is interwoven into the fabric of cooperative work and can be described as taking place in several dimensions (who, what, when, how etc.?) within cooperative work practices.

Articulation work can take place in several dimensions, a tentative list could look like this: (a) Articulation in relation to actors, e.g. who is relevant and available in connection to a particular project. (b) Articulation in relation to responsibilities, e.g. who is accountable for what. (c) Articulation in relation to tasks, e.g. what is to be done and in what order. (d) Articulation in relation to activities, e.g. how far has the others come. (e) Articulation in relation to conceptual structures, e.g. how to classify. (f) Articulation in terms of resources, e.g. who has access to resources and to what extend (Schmidt 1994, p.15.).

In order to perform this articulation work persons engaged in cooperative activity will typically have to engage in communication in some way (Dix 1996, p.7). The two circles labelled "P" in figure 1 represent these participants. In addition, if they are engaged in cooperative work, there will typically be artifacts on which they are working, either in solid physical form or in digital form (Dix, 1996, p.8). These artifacts are labelled "A" in figure 1 – the artifacts of cooperative work.

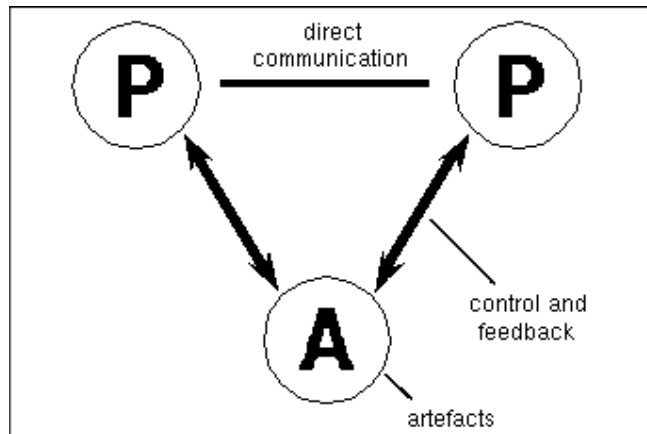


Figure 1. Communication in articulation work (Dix 1996, p.8)

On computers the artifacts are typically in the form of groupware system, in the non-digital domain they can take almost any form.

This articulation is always done in relation to a particular *field of work*, a particular context. The field of work is the conceptualisation of the work setting, the setting that constitutes the focus of the cooperative work effort, and thus also constitutes the context for the articulation work. This setting can be described, in abstract terms, as constituted by a constellation of mutually interacting artifacts and processes, actual or anticipated, physical or social as well as the interfaces to these artifacts and processes, such as sensors, tools and representations (Schmidt 2002, p.20). It is this context or field of work that mediates the cooperative work; the field of work constitutes the focus and the extent of the cooperative work effort. The field of work changes dynamically in relation to occurrences that can be internal or external to the present state of the field of work (Schmidt 1994, p.15).

Articulation work is thus always taking place within a field of work and in relation to actors, responsibilities, tasks, activities, conceptual structures, resources and the material work setting. Different constellations of these dimensions in turn constitute what can be described as different cooperative work arrangements. More precisely a cooperative work arrangement can be considered to be an ensemble of interdependent actors constituted in and by a system of interdependent activities (Schmidt 1994). It is a transient arrangement of actors emerging contingently to meet specific requirements, only to disperse again if and when the need for the arrangement is no

longer present (Schmidt 2002, p.23). The cooperative work arrangement and their field of work mutually constitute each other. As the field of work changes the cooperative work arrangement often have to adapt and follow suit, similarly changes in the work arrangement can bring about changes in the field of work (Schmidt 2002). If for example a machine in a production facility needs to be realigned a specialist may have to be temporarily added to the cooperative work arrangement. If the specialist is not present the machine perhaps cannot be used and is excluded from the field of work.

Further more, we can note that in order to be able to articulate the cooperative work effort, the members of the cooperative work arrangement need at least some level of common knowledge of the field of work and beyond that some degree of mutual cultural understanding (Dix 1996, p.8).

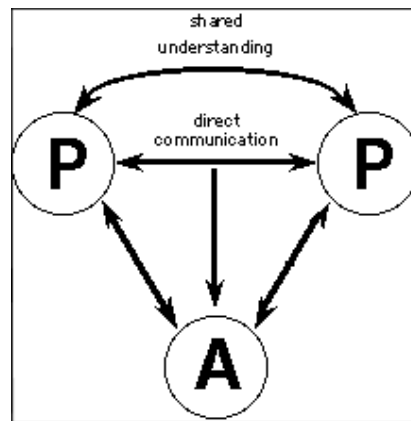


Figure 2. Meta-information (Dix 1996)

Knowledge and experience with the field of work, the cooperative work arrangement and the larger enclosing cultural and social setting can be described as shared understandings among the members of the cooperative work arrangement. One unison understanding of the field of work is not present among the actors making up the cooperative work arrangement, but overlapping multiple perspectives are, and part of the articulation work is aimed at negotiating these overlapping and sometimes conflicting perspectives on the work at hand. The point is that shared or overlapping understandings are not defining features or preconditions of cooperative work but rather local and temporary closures, obtained and maintained only as a result of an

articulation effort. The phenomena of overlapping understandings imply that the actors are just partly knowledgeable of each other's work and there is therefore a place for partly autonomous behaviour (Schmidt 2002, p.19).

Central to the description of practices of articulation work within the field of CSCW is the concept of *mutual awareness*, sometimes also termed peripheral awareness. The concept of mutual awareness holds that the articulation of activities in cooperative work often entails the creation and continual recreation of mutual awareness of the activities, concerns and intentions of the other members of the cooperative work ensemble (Schmidt 1994, p.60). The practices of mutual awareness can take the form of scanning for signs that are meaningful¹ in connection to the work process at hand. As complementary action actors will select actions that lend meaning to the cooperative work process, and make them "publicly visible" in order to make it possible for others to monitor them (Heath & Luff, 1992). These articulation practices based on mutual awareness mostly takes place implicitly and almost unnoticed, and are often observed in relatively small work settings. Control rooms is the prime example, in fact the concept of mutual awareness was coined in connection to ethnomethodological studies of control rooms (Heath & Luff, 1991; Heat & Luff, 1992).

However, cooperative work is not only coordinated through the attention to co-workers actions and display of bodily gestures. It is also coordinated through the material work setting, through the use of artifacts (Schmidt 2000 p.5). In some chases cooperative work is coordinated through the artifact rather that by direct face-to-face interaction or by other forms of verbal interaction, for instance (Dix 1996). It is this form coordinative practices, namely artifact based coordination of collaborative work that makes up the main topic of this thesis as mentioned above.

¹ What is meaningful to monitor or display form the point of view of the individual actor is closely connected to the actor's knowledge and experience with the work setting and ultimately with the world the actor is born into. In making sense of what others are doing or will do, an actors draws on his/her knowledge of the work setting, the tools, the concepts, the normal routines and procedures, and ultimately on general culture. Actors do not aimlessly monitor their surroundings; they scan for indicators of states or state changes of relevance. Similarly actors select to display what they find relevant to others. Typically the display and monitoring of meaningful and relevant actions is done effortlessly by the competent actor (Schmidt 2000, s.4). Making sense is effortless to the skilful practitioner, to the novice however, it is an entirely different matter.

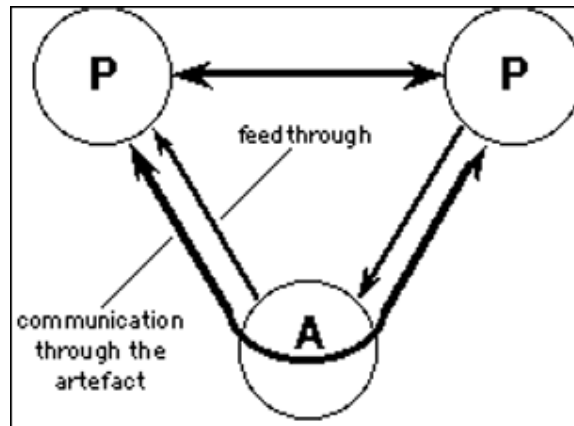


Figure 3. Articulation through the artifact (Dix 1996)

Further more, and perhaps of interest to CSCW, a particular class of artifacts have also received increasing amounts of attention, especially in connection with the rise of the paradigms of ubiquitous computing, namely digital artifacts (Beigl et al., 2002). The research effort within the area of ubiquitous computing can be described as driven by a desire to make computes vanish into the background of everyday life (Weiser 1991, p.1). Weiser (1991) finds that contemporary computers often get in the way of work rather than help it along. He compares the development of computer technology to the development of the technology of writing: “The state of computing is perhaps analogous to the period where scribes had to know as much about making ink or backing clay as they did about writing” (Weiser 1991, p.1). He finds that computers require much more active attention than desired: “Computers are approached through complex jargon that has nothing to do with the tasks people actually use them for” (Weiser 1991, p.1). Weiser suggest resolving this problem of computers getting in the way of work by means of transforming them into small digital artifacts and integrating them into the background of everyday life. According to Weiser (1993), this is not a problem of GUI interface design, this is not a problem of multimedia design, it is a property of the whole context of use of the PC with its cumbersome weight, size, screen, keyboard, mouse etc. The challenge, again according to Weiser (1993), is to create a new kind of relationship of people to computers, one in which the computer is out of the way, allowing people to just go about their lives (Weiser 1993, p.76). We could suggest that this situation could also be helpful to the field of CSCW: flexible and fluent systems of computer support for cooperative work could be envisioned and designed if computers where present in the

form of ubiquitous digital artifacts² and not almost solely in what can be described as the cumbersome and attention demanding forms of contemporary PC's. Following this view, the question of artifacts and how they are employed in collaborative work could be seen as being of prime importance: In order to make computers vanish into digital artifacts of everyday life and take advantage of this capability for the support of collaborative work, we have to understand how artifacts are constituted and used in collaborative work in the first place? This question of how artifacts are constituted and used in collaborative work is posed in this thesis.

Turning to the research agenda within the field of CSCW, it can be noted that in the recent years CSCW researchers have increasingly come to realize that the material work setting and its population of artifacts have a crucial role to play in the coordination of cooperative work. To begin with, ethnomethodologically informed studies demonstrated that material artifacts are key in the understanding of coordinative practices (e.g. Harper & Hughes 1993; Harper, Hughes & Shapiro 1989; Harper, Hughes & Shapiro 1991). Other ethnomethodologically informed studies pointed out how actors skilfully employ the affordances of the material work setting in order to articulate their cooperative efforts (Heath & Luff 1991; Heath & Luff 1992, Suchman 1993; Suchman & Trigg 1991). These and other attempts were reflected in early conceptualising cooperative work (Schmidt & Wagner 2002a, p.1).

At present the focus on the material work setting and on artifacts is notable within the field of CSCW. A shift of focus has occurred: While the frequency of inquiries or even references to artifacts in CSCW publications for the first many years were low, the present frequency of papers, in CSCW publications, on artifacts can be said to be quite high. The role of artifacts in cooperative work appears to have moved close to the center of attention in the field of CSCW (Schmidt & Wagner 2002a, p.2).

The ethnomethodologically informed studies pioneered, as mentioned above, the study of the role of artifacts in cooperative work. In these early ethnomethodologically informed studies the conceptualisations of conversation analyses were prominent. The concepts of conversation analysis is still to be found

² Work in this area is seen under way considering for instance Beigl (2002), Gaver (2002), Nilsson (2000), Schmidt (2002).

in recent ethnomethodologically informed studies, however, in recent years the analysis is made with stronger emphasis on the material work setting. There has been a shift of conceptual framework. A shift that can be observed in the increasing use of theories such as “activity theory”, “distributed cognition”, and “actor-network theory” in the field of CSCW. These theories are not only seen as providing a framework for CSCW research and design, they are also seen as bringing focus to the role of artifacts in human action and interaction (Schmidt & Wagner 2002a, p.2). Unfortunately however, these theories³ tend to de-materialize artifacts: Activity theory’s concept of “psychological tool” (Vygotsky 1979) spiritualises material artifacts, while distributed cognition (Hutchins 1996) treats artifacts as vehicles of representations, thus both can be said to de-materialize artifacts (Schmidt & Wagner 2002a). We shall return to a discussion of this below. The point, for now, is that while the central role artifacts have to play in cooperative work has been recognized, the concept of artifact in CSCW remains ripe with mentalist and cognitivist precepts, as observed by Schmidt (2002). This is unfortunate because work is material in nature and need to be studied as such (Schmidt 2000). There is a need for an approach that leaves room for the material side of artifacts as well as the non-material (social, mental, psychological, cognitive) side of artifacts.

Epistemology, ontology and artifacts

In an attempt to ground a breakaway from unbalanced mentalist or materialist approaches to the study of artifact based articulation work, and take a step towards a balanced approach where the material side of artifacts as well as the non-material side (social, cognitive, psychological) is considered equally, questions of ontology and epistemology will be raised below. That discussions point of departure will also consider the debate on rationality and relativism:

“The debate on rationality and relativism seems se to become interminable and insoluble. ‘Debate’ is a misnomer; rather it is all to often a contest that takes place from fixed positions and in which both sides draw sustenance from the intellectual weaknesses of their opponents.” (Hirst 1985, p.86).

³ These theories and their ability to clarify issues involving the use of artifacts in cooperative work will be discussed at length in section one.

The Paul Hirst quote above illustrates what Richard J. Bernstein, in his book “Beyond Objectivism and Relativism”, describes as an uneasiness that has spread throughout intellectual and cultural life:

“It [the uneasiness] affects every discipline and every aspect of our lives. This uneasiness is expressed by the opposition between objectivism and relativism, but there are a variety of other contrasts that indicate the same underlying anxiety: rationality versus irrationality, objectivity versus subjectivity, and realism versus antirealism. Contemporary thinking has moved between these and other related extremes.” (Bernstein 1983, p.1).

It is important to clarify what is meant by “objectivism” and “relativism”.

In modern times the term “objectivism” has been used to designate the claim that there is a world of objective reality that exists independently of us and has a nature or essence that we can know. It has been linked to the epistemological distinction between subject and object. Objective reality is presumed to be independent of us subjects, and true knowledge is achieved when a subject correctly mirrors or represents objective reality (Lübcke, 1983). Bernstein goes even further that that and broadens the concept to mean a basic conviction that there is a permanent, ahistorical framework to which we can ultimately appeal in determining the nature of rationality, knowledge, truth and reality. Objectivism, in Bernstein’s view, is closely related to the search for an Archimedes point (Bernstein 1983, p.8). In relation to the field of CSCW, it can be noted that activity theory, based on the philosophy of Marxism, assumes that human beings live in an objective reality that determines and shapes subjective phenomena (Kaptelinin 1995, p.191). Activity theory has its Archimedes point in other words. This solid point of departure makes it possible to search for an objective account of subjective phenomena within the activity theory framework (Kaptelinin 1995).

Relativism, in its strongest form, is the basic conviction that the concepts that has been taken to be fundamental in the sciences – concept like rationality, truth, reality – must all in the final analysis be understood as relative to a specific culture, society, conceptual framework, theory, or form of live. The relativist believes that there is a

non-reducible plurality of such concepts, and challenges that any one of these concepts can have a univocal significance (Bernstein 1983).

The debate between objectivists and relativists has a remarkable continuity, dating back to the days of Plato's attack on the Sophists (Bernstein 1983 p.8). The relativist accuses the objectivist of mistaking what is at best historically or culturally stable for eternal and permanent truths. Objectivists in return have argued, ever since Plato, that relativism when clearly stated, is self-referentially inconsistent. Because implicitly the relativist claims that his or her position is true, yet the relativist also insists that truth is relative. The relativist position can only be relatively true (thus, it can also be false). One cannot consistently state the case for relativism, without undermining it (Bernstein 1983, p.9).

In relation to our study of artifacts in collaborative work practice, which side should we choose, in the debate on objectivism and subjectivism? Should we declare ourselves objectivists and search for an Archimedes point, in order to determine what artifacts truly is and discover their true role in coordinative practices. Or perhaps we should swear to the relativist view point and claim that the role of artifacts, indeed the question of what an artifact really is, can never be discovered with absolute authority - it can only be described from a particular and relative viewpoint that only make claim to a relative truth.

Whatever position we take, we will join the ranks of the damned and take up a position in a locked debate, ongoing since the days of Plato. We will open our self up to one of the criticisms noted above.

However, it seems there is a more fruitful path to take, than the one leading into the debate on objectivism vs. relativism. Following Mathiassen (2000) I will claim that the debate is best bypassed. We need to focus not so much on the possibility of true knowledge, but on mans general possibilities of existence⁴ (Mathiassen 2000, p.27). That could turn out to be fruitful.

⁴ Mathiassen (2000) use the Danish phrase: *menneskets mulighedsbetingelser*.

Sadly however, inquires into ontology can all too often end up reducing the world we live in to a construct. Take for example Denzin (1997):

“Humans are always already tangled up (...) in a second hand world of meaning and have no direct access to reality.” (Denzin 1997:xvi.)

This tendency to neglect and deny human access to the materiality that surrounds us can also be found in prevailing theories in the field of CSCW, as briefly noted in the introduction. Activity theory and what can be described as the subsequent theory of distributed cognition de-materialize the concept of artifact, and in turn (unwittingly) disregard the material nature of the world surrounding us (Schmidt 2002, p.3).

Activity theory, as contemporary advocates of the framework understands it, does pay attention to the materiality of the context of human action. Take for example Bonnie Nardi, in the book “Context and Consciousness – Activity Theory and Human-Computer Interaction”:

“Activity theory (...) extend the concept of consciousness past an idealistic, mentalistic construct in which only cognitive resources and attention “inside the head” are at issue, to a situated phenomenon in which one’s material and social context is crucial” (Nardi 1996, p.13).

Activity theory (as well as distributed cognition) diverges from other cognitive theories by incorporating the context of cognition (Halverson 2002, p.4), but does that include the materiality of the context, as Nardi (1996) claims? In order to pursue this question, we shall have a look at the roots of activity theory and distributed cognition.

Contemporary activity theory and the subsequent theory of distributed cognition builds on L.S. Vygotsky a Russian psychologist and his successors Leont’ev and Luria’s work initiated in the 1920s and 1930s (Susi & Ziemke, 2001). Vygotsky had an ambition to ground his theory in historically evolving and culturally specific material practices, inspired by Marxist theory (Schmidt 2002, p2). His ambition was undermined, however, by his concept of “psychological tools”:

“1. In the behaviour of man we encounter quite a number of artificial devices for mastering his own mental processes. By analogy with technical devices these devices can justifiably and conventionally be called psychological tools [...].3. Psychological tools are artificial formations. [...] They are directed toward the mastery of [mental] processes – one’s own or someone else’s – just as a technical device is directed toward the mastery of processes of nature. 4. The following may serve as examples of psychological tools and their complex systems: language, different forms of numeration and counting [...], writing, diagrams, maps, blueprints, all sorts of conventional signs, etc” (Vygotsky 1979).

The concept of psychological tool is fundamentally problematic in that it suggests that skilful action is somehow determined by stable or concrete mental structures (psychological tools), the concept downplays the dynamic and temporal nature of human mental processes and denies materiality a part to play (Schmidt 2002, p3.). This de-materialised and all encompassing definition of the concept of artifact has continued in the tradition of activity theory. Kuutti (1996) to take one, list instruments, signs, procedures, machines, methods, laws, form of work organisation and even activity theory as examples of artifacts. Kuutti (1996), in the tradition of Vygotsky, fails to make explicit the importance of materiality, especially in connection to the concept of artifact. A critique that applies to activity theory in general as it is advocated by Nardi (1996), Kuutti (1996) and Kaptelinin (1996). Distributed cognition does no better.

Distributed cognition uses the framework of classical cognitive science, slightly modified, in order to be applied to a unit of analysis that is larger than a person (Susi 2000 & Ziemke, p.23). Cognition, within the distributed cognition framework, is viewed as being distributed across a system of actors and artifacts localized in a historical and social context (Hollan et al. 2000). This framework, as contemporary advocates understand it, does pay attention to the material world. Take for example Hutchins (1995):

“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” (Hutchins, 1995, p.266).

Hutchins draws attention to the “details of these processes as they are enacted in the activities of real persons interacting with real material media”, but on closer inspection material media or artifacts merely serve as vehicles of representations. That materiality plays a part is noted, but it is never explicitly and systematically explored. As Hutchinson describes the phenomena in connection with his and Klausens analysis of cooperative work in an airline cockpit:

“We can see that the information moved through the system as a sequence of representational states in representational media. From speech channel to internal memories, back to speech channels, to the physical setting of a device” (Hutchins & Klausen 1996, p.27).

Further more, information seems to migrate unchanged from mind to artifact to mind, maintaining unity and identity (Schmidt & Wagner 2002a, p.3) across materiality, minds and time. The practice of producing and reproducing meaning is neglected - order is presupposed. As Schmidt & Wagner (2002a) observe, by presuming the practice of producing and reproducing order, what is to be investigated and understood is taken for granted, in line with the idealistic precepts of cognitive science, and artifacts are treated as vehicles of stable units of information (Schmidt & Wagner 2002a, p.4).

Both activity theory and distributed cognition are both first and foremost, theories about cognition (Halverson 2002, p.3), and does not include the notion of materiality in a strong sense as we have seen. There is a need for an approach that leaves room for the material side of being in the world as well as the non-material (mental, psychological, cognitive) side of being in the world. This approach must build on an ontology that includes both. I will, following Taussig (1993), claim that:

“We live between the real and the real made up” (Taussig 1993, p.xvii).

Such an understanding of reality leads us beyond purely mentalist or purely materialist perspectives and includes the material side of being in the world as well as the non-material (mental, psychological, cognitive) side of being in the world. It does so in the sense that it employs on the one hand a “real” reality (material facts like: paper is easily bend, stone is not) and on the other hand makes use of “the real made

up”, social and mental constructs that structure our lives (in a very “real” way) such as plans or work ethics. Neither the mental side of being in the world nor the material side of being in the world is given precedence at the expense of the other. The truly interesting part, for our purpose, is of course how these two “realities” interplay in human practices, such as shaping and using artifacts in cooperative work⁵. In the investigation of these questions, it could be fruitful to employ a concept of artifacts that builds on the notion that we live between the real and the real made up.

Artifacts between the real and the real made up

The following analysis explicitly and implicitly employs the notion that we live, produce and reproduce our artifacts between the real and the real made up. In relation here to we can perhaps offer a preliminary and very abstract idea of what makes up an artifact in actors practice: it is equally a social and a material phenomena it is a process rather than a stable entity. Consider the following: If we follow Taussig (1993) maybe we can describe an artifact as constituted between the real (physical phenomena: materiality etc.) and the real made up (social practice: sign system, etc.). Perhaps what make an artifact meaning full to an actor is her practice and the interplay of the real and the real made up. Take a material thing, a box with multi collared lights standing in a cross road, is it meaning full without the social construction we term traffic laws? Is it not the combination of the box with multi collared lights and the traffic laws, that in the context of “traffic” practice, makes up the artifact: traffic light? Can we separate the artifact from the creation of meaning? Perhaps what makes an artifact, and what makes it meaning full, is the same process. Perhaps an artifact is constituted both materially and in and by the process of the creation of meaning, and cannot tenably be considered apart there of. Considering this position on what constitutes an artifact, we lean towards studying the process of artifact based coordination work, what makes up the artifact and not so much towards an isolated view of the artifact. Can we suggest that this is in line with the research conducted by Schmidt (2002), Schmidt (1997) and Schmidt & Simone (1996) that gives emphasis to the process of articulation work mediated by artifacts? Perhaps we

⁵ Writing for instance, evolved in close connection with the development of writing materials (Harris 1986), the “real” the material side of reality and the “real made up”, interplayed in the development of a practice of writing.

can go as far as stating that an artifact is not a thing but a practice in the sense that an artifact in both socially and physically constituted, it is only “there” as a consequence of this constitution or practice of a social and material nature. In order to provide another example of this view of an artifact, let us consider something as mundane as a drinking glass: is it not the glass ability to hold water (a physical affordance) and our ability to know this, fill, pour and swallow the water (a learned skill associated with our biology), that makes up the artifact? Would the drinking glass be a drinking glass, would it be meaningful without the skill of drinking, without the practice of drinking. This is not an attempt to make the artifact into a purely social construction. If we paraphrase what Putnam have remarked: “you cannot fly in a social construction” (Putnam 1981) we can remark that, “you cannot drink from a social construction”. It is important to acknowledge that a drinking glass would not be a drinking glass was it not for its physical ability or affordance of holding water.

In this view it is the combination of practice (in the case of the glass: drinking) and physical affordances (in the case of the glass: holding water) that makes up the artifact. Let us in a preliminary manner continue to the coordinative practices of collaborative work based on artifacts.

In the following sections, we shall have a look at two types or modes of coordinative practices based on artifacts. On the one hand artifacts based articulation work. On the other hand a form of coordinative practice we shall conceptualise as stigmergy.

Artifact based articulation work

As mentioned above, in some chases cooperative work is articulated through the artifact rather that by direct face-to-face interaction or by other forms of verbal interaction, for instance.

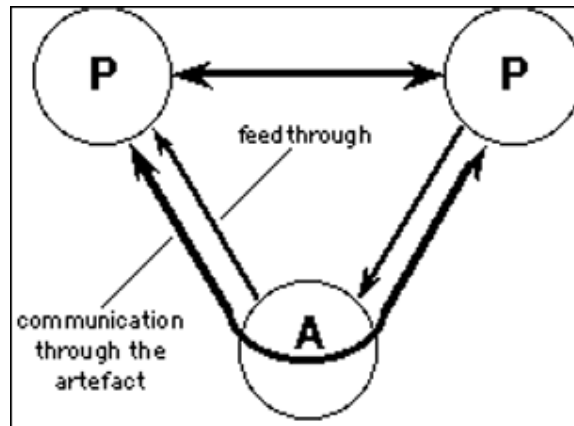


Figure 4. Feedthrough (Dix 1996)

Dix (1996) terms this kind of articulation “feedthrough”, and states that the presence of feedthrough effectively creates an additional channel of communication **through** the artifacts themselves. Further more, Dix (1996, p.9) states that this form of articulation is often more important than verbal direct communication.

In addition to Dix’s feedthrough concept, this mode of articulation work through the artifact has been described and conceptualised as interaction through the field of work by Schmidt (1997). In addition Schmidt (1994) coins and employs the concept of “coordinative artifacts”. Schmidt (2002, p.33) gives the follow examples of what could be considered to be coordinative artifacts found in contemporary workplaces:

- “(i) Product standards, blueprints, drawings, ‘style sheets’ may serve as ‘templates’, that is, artifacts that specify the properties of the result of individual contributions. By defining interfaces between local practices, such artifacts may provide means for a relative decoupling of interdependent activities and hence for reducing the complexity of articulation work.
- (ii) Bulletin boards, archives, taxonomies, maps, charts, procedures, schedules, etc. may reduce the cost of taking remote or global concerns into account by making remote or global concerns ‘visible, e.g., by providing representations of interdependencies, by providing representations of the state of affairs, by highlighting crucial issues, by affording the calculation of possible or probable remote effects of local actions, etc.
- (iii) Calendars, clocks, agendas, time tables, flight plans, project schedules, production plans, production control systems (MRP systems, kanban systems), etc. may be instrumental in synchronizing local activities that are otherwise decoupled and performed concurrently or intermittently. Alerts, calls, and reminders can be seen as similar but more intrusive means of synchronization.

(iv) Flight deck checklists, safety procedures, flight databases, workflow systems, production control systems, etc. may be instrumental in prescribing certain aspects of local activities (steps to be taken or not taken the sequence of steps, alternative steps, criteria, etc.). By stipulating the course of action in certain ways and thus curtailing parochial aspects of those practices, such coordinative artifacts are introduced and used as means of increasing operational safety, reliability, efficiency, e.t.c.“ (Schmidt 2002, p.33).

Schmidt (2002, 1994) conceptualises the above-mentioned artifacts as “coordinative artifacts”. Coordinative artifacts are the artifacts that are mediating coordinative practices by virtue of a pre-established coordinative protocol (Schmidt 2002, p.3). In cooperative work settings characterised by complex task interdependencies, the articulation of the cooperative- and distributed activities requires specialized artifacts, which by employing of a pre-established coordinative protocol, are instrumental in reducing the complexity of articulation work and in turn diminishes the need for ad hoc negotiation of the work process (Schmidt & Simone, 1996). A coordinative artifact can be thought of as constituted by two parts. On one hand a coordinative protocol of a social nature in the form of a set of agree-to-procedures and conventions that to competent members of the cooperative ensemble, stipulates the responsibility of the different roles in the cooperative work group. On the other hand we have the persistent part of the artifact in which the protocol is imprinted (Schmidt & Simone, 1996 p.165). We can notice, that this definition of a coordinative mechanism or coordinative artifact seems to be in accord with the very abstract idea of an artifact that was given above: an artifact is equally a social and a material phenomenon it is a process rather than a stable entity. We can perhaps suggest, utilizing Taussig (1993) to examine Schmidt & Simone’s (1996) characterization of coordinative artifacts, that the coordinative protocol represents what Taussig terms “the real made up” while the physical form of the artifact represents the what Taussig terms “the real” a more material part of the artifact, “the real” serves as a body of inscription for the protocol and allows the protocol to be objectified and to obtain some relative permanence, as observed by Schmidt & Simone (1996).

It could seem that our idea of an artifact as an equally social and material phenomenon, a process rather than a stable entity, can be described as being in sync with Schmidt & Simone’s (1996) concept of coordinative artifacts. Schmidt and

Simone's (1996) characterization of a coordinative artifact makes it tenable to distinguish between artifacts in general, and coordinative artifacts that mediate coordinative practices by virtue of a pre-established coordinative protocol.

However, consider the following example by Dix (Dix 1996, p.9):

“Imagine you are moving a large piano. You may say things to each other - “move your end up a bit”, “careful of the step” - but in fact the most important thing is the feel of the other person's movements through the movements of the piano. This sort of communication is effective partly because it is tied so intimately to the work itself, and partly because it is implicit, unconsciously noticed and acted upon.”

The piano is obviously designed with the practices of music in mind, and not with practices of coordination in mind, as the case is with the coordinative artifacts mentioned above. Nevertheless the piano mediates the process of coordination. This is mentioned in order to let us consider that all artifacts have the potential for mediating cooperative work. This point and the concept of coordinative artifacts shall be explored below, in part by employing the concept of stigmergy.

Stigmergy

Susi & Ziemke (2000) draws attention to the concept of stigmergy in relation to the field of CSCW in their article entitled “Social Cognition, Artefacts, and Stigmergy: A Comparative Analysis of Theoretical Frameworks for the Understanding of Artefact-mediated Collaborative Activity”. Susi & Ziemke reviews the theoretical positions of activity theory, distributed cognition and situated action and comes to the conclusion that all three theoretical positions have a something in common, in relation to how they describe the role of artifacts in collaborative activity. The common denominator, according to Susi & Ziemke (2000), can be described in terms of the concept of stigmergy (Susi & Ziemke 2000). A closer look at the concept of stigmergy may be warranted.

In the late 1950s Grassé (1959) coined the concept of stigmergy⁶ during his study of the behaviour of social insects (Theraulaz & Bonabeau, 1999, p.97). Grassé and his scientific field of was in need of a model to explain an apparent paradox in the behaviour of social insects: looking at a group of social insects they all seem to be cooperating in a organised, coordinated manner (building nests etc.), but looking at each individual, they seem to be working as if they where alone and not involved in any collective behaviour (Theraulaz & Bonabeau, 1999, p.99). This apparent paradox, Grassé offered to demystify, utilising the explanatory power of the stigmergy concept: collaborative work is coordinated through the evidence of work previously accomplished. Grassé showed that the regulation of building activities in social insects does not depend so much on the workers themselves as on the nest structure. A stimulating configuration triggers a building action of a termite worker, transforming the configuration into another configuration that may in turn trigger another (possibly different) action performed by the same termite or any other worker in the colony (Grassé 1959).

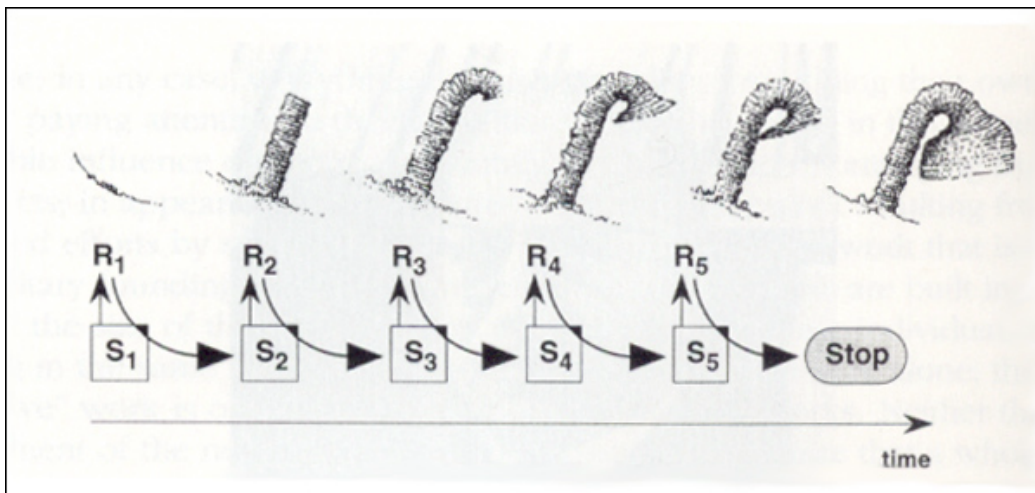


Figure 5. Stimulus-response sequence leading to the construction of the mud funnel in the nest of the Eumenid wasp *Paralastor* sp. Each new building stage n is completed after a stimulus S_n triggers a new ensemble of building actions R_n . The completion of each building stage n gives rise to a new stimulus S_{n+1} that triggers a new building action R_{n+1} leading to the construction of the new building stage $n+1$. When the fifth stage has been completed, there exists no more stimulus on the funnel to trigger new building actions and the construction stops (Theraulaz and Bonabeau 1999, p.102).

⁶ From the Greek *stigma* : outstanding sign, and *ergon*: work.

It can be instructive to consider nest construction in solitary species to get a feel for the “algorithm” followed by the individual insect. The experiment performed by Smith (1978) on a solitary wasp shed some light on this issue. The nest construction of the wasp *Eumenid Paralastor* takes place as a sequence of stimulus-response actions in which the completion of one stage provides the commencement of the next (see figure 6). A wasp begins its nest construction with the excavation of a narrow hole in the ground (approximately 8 mm wide and 8 cm deep). When the nest hole has been completed, the wasp begins to erect a large mud funnel above the hole. The funnel is built in five distinct stages from mud pellets applied in a stimulus-response sequence. Stage 1 involves the building up of the funnel until it reaches a certain length (approximately 3 cm). At stage 2 the wasp ceases to build straight upwards, and applies more mud to one side of the funnel and in the process constructs a curve in the stem of the funnel. Once the curve has been completed, stage 3 begins with the formation of a bell like structure (approximately 2 cm in diameter). The flange of the bell is widened at stage 4 and at the final stage 5 the sides of the bell are formed (Smith 1978). At the end of each building stage, the stimuli for the responses that lead to the next stage are a consequence of the wasp’s earlier building activity. Smith chose to disrupt this sequence in his experiment. What happens if the stimuli that triggers the start of a previous building stage, are encountered by the wasp at a later building stage: what happens, for instance, if the wasp after the work on stage 3 encounters the stimuli that started stage 1. Smith made an experiment to answer this question: A spherical hole located in the neck of the funnel (the stimuli for the start of stage 1 was a spherical hole) is made just after Stage 3 has been completed (see figure 6). After examining the hole several times, the wasp begins to construct a new funnel on top of the hole in the first funnel (Smith 1978). This result is instructive for anyone who wishes to understand the concept of stigmergy (Theraulaz & Bonabeau, 1999 p.103).

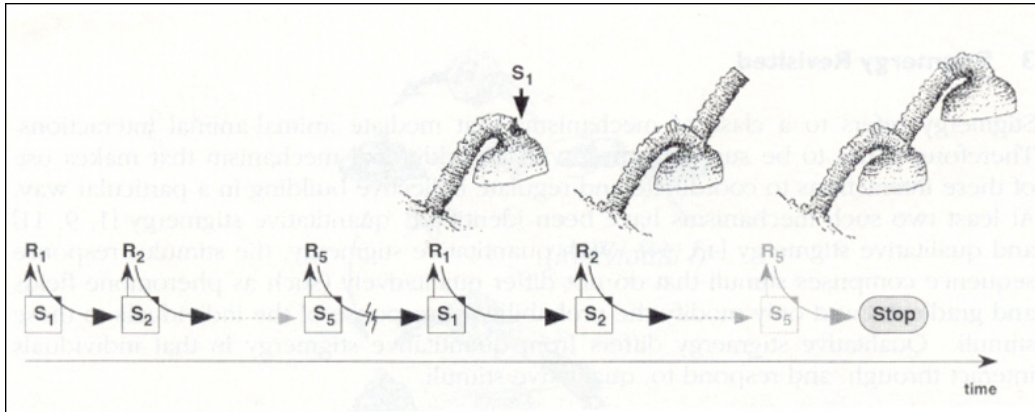


Figure 6. The construction of an abnormal mud funnel in the nest of the Eumenid Wasp *Paralastor* sp. When the funnel is almost finished, a hole is made in the funnel (indicated by the arrow). The hole is similar to stimulus S1 that is responded to be the wasp by starting to build a funnel. The wasp builds a new funnel on top of the first one almost completed (Theraulaz and Bonabeau 1999, p.103).

There are two consequences of this behaviour.

First, the order in which stimuli for the construction arises must follow a precise sequence, for the orderly execution of the building activity, a non-orderly sequence of stimuli will lead to abnormal and redundant nest structure.

Secondly and more importantly for the purpose of understanding the concept of stigmergy: if one wasp does not distinguish the product of its own activity from the product of that of another wasp, the two wasps can in principle work at completing the same nest structure. One wasp could continue the work of another at wasp at any stage of construction. Such behaviour may in turn be a step towards indirect cooperation between social insects. This is precisely the phenomenon that Grassé had in mind when he coined the concept of stigmergy (Theraulaz & Bonabeau, 1999 p.103): collaborative work is coordinated through the evidence of work previously accomplished.

Grassé developed the concept of stigmergy during his study of termites. However, it has since then been used and applied to other groups of social insects (Wilson 1975), not least in the study of ants (Hölldobler & Wilson 1994). Over the last decade or so the concept of stigmergy has been introduced to the field of telecommunication

especially in connection with the development of algorithms for network traffic, these algorithms are sometimes termed “ant algorithms”, (White & Pagurek, 1998) and to the field of robotics (Dorigo et al, 2000)

White (1997) suggests based on the work of Wilson (1975) and (Hölldobler & Wilson 1994) to distinguishing between what he terms sematectonic stigmergy and sign based stigmergy (White 1997, p.1). Sematectonic stigmergy is in White’s view a term for stigmergy in cases where all relevant interaction is done directly through the work at hand, and makes direct contributions to the work at hand. Following White (1997), in sign based stigmergy something, which makes *no* direct contribution to the task, is deposited in the environment and guides the work at hand (White 1997). Whether or not it is tenable to designate these “deposits in the environment” signs and whether or not signs cannot contribute directly to the work at hand, as it seems implicitly stated by White (1997), can indeed be debated and we shall do so below. For the time being lets give some examples of what White could term “sematectonic stigmergy” and lets follow with an example of what he could term sign based stigmergy.

An example of what could be termed sematectonic stigmergy in Whites terminology is termite nest building as pictured in figure 7:

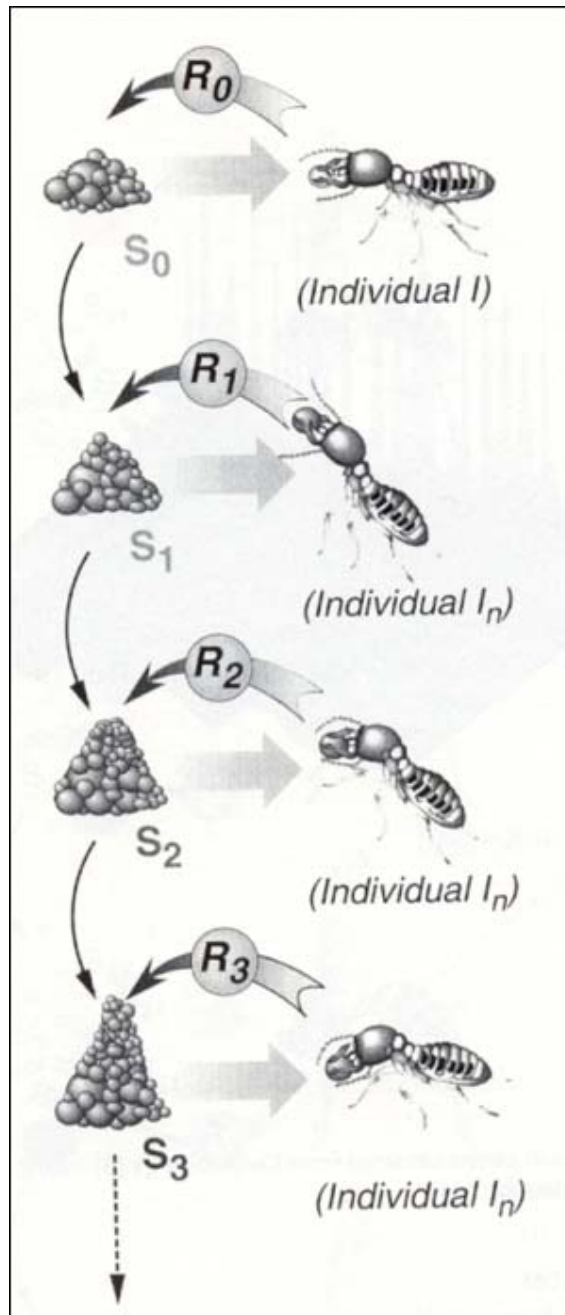


Figure 7. An example of a sematectonic stigmergic process as it appears in the construction of pillars in termites. Assume that the architecture reaches state S_0 , which triggers response R_0 from worker I. S_0 is modified by the action of I (e.g., I may drop a soil pellet), and transformed into a new stimulating configuration S_1 that may in turn trigger a new response R_1 from I or any other worker I_n and so forth. The successive responses R_1, R_2, \dots, R_n may be produced by any worker carrying a soil pellet. Each worker creates new stimuli in response to existing stimulating configurations. These new stimuli then act on the same termite or on any other worker in the colony (Dorigo et al, 2000, p.852).

Let us also, for the sake of illustration, give an example of what White could term sign based stigmergy: White (1997) refers to the foraging behaviour of ants: Individual ants are behaviourally very simple creatures. They have a very limited memory and exhibit individual behaviour that appear be arbitrary to a large extent. Acting as a collective however, ants manage to perform a variety of tasks with great consistency. A few examples of such collective behaviour, which has been explained employing the concept of stigmergy, are (Hölldobler & Wilson 1994; Franks 1989):

- Forming bridges
- Raiding particular areas for food
- Building the nest and defending it
- Carrying large items
- Emigration of a colony
- Finding the shortest route from the nest to a food source

These behaviours all emerge in interaction between large numbers of individual ants and the concept of stigmergy has been employed to explain this interaction, in relation to employing the concept of stigmergy on Ant's and other species of social insects collective behaviour. Depending on the species, ants may lay pheromone (a hormone) trails when travelling from the nest to a food source, or from food to the nest, or when travelling in either direction. They also follow these trails with fidelity that is a function of the trail strength, among other variables. Ants drop pheromones as they walk by stopping briefly and touching their gaster, which carries the pheromone secreting gland, on the ground. The strength of the trail they lay is a function of the rate at which they make deposits, and the amount per deposit. Since pheromones evaporate and diffuse away, the strength of the trail when another ant encounters it is a function of the original strength, and the time since the trail was laid. Most trails consist of several superimposed trails from many different ants, which may have been laid at different times; it is the composite trail strength, which is sensed by the ants (Beckers et al., 1992). The principles applied by ants in their search for food are best explained by an example as given in (Schoonderwoerd et al, 1996):

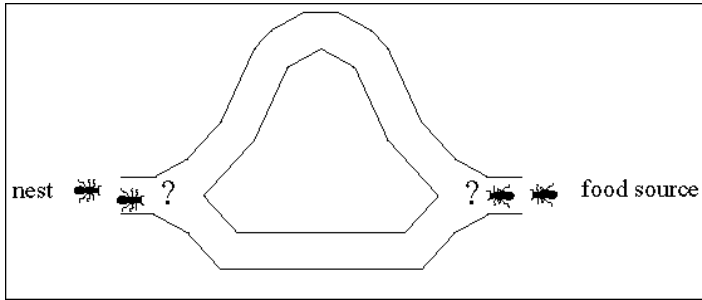


Figure 8: Ants have a decision to make (Schoonderwoerd et al, 1996, p.6).

Figure 8 illustrates two potential routes between nest and food-source. At the outset, an ant arriving at a T-crossing (a choice point) makes a random decision with a probability of 0.5 of turning left or right. Now, suppose there are two ants departing from the nest, looking for food, and two ants returning from the food source to the nest. Let the ants be of a type such as *Lasius Niger*, which deposits pheromones when traveling both to and from the nest. If one ant from each pair turns left, and the other turns right, after a while a situation occurs that could be depicted as done in figure 9. The lines on the paths represent the pheromone trails. The ants that chose the shorter branch have arrived at their destination, while the ones that chose the longer branch are still on their way. Ants initially select their path with a 0.5 probability for both branches, as there is no pheromone on the paths yet. If there is pheromone present, there is a higher probability of an ant choosing the path with the higher pheromone concentration, i.e. the path where most ants have passed along recently. Ants arriving and finding the situation as shown in figure 9, are more likely to choose the shorter more traveled path, because that is where the concentration of pheromone is higher. This in turn could reinforce the amount of pheromone on the shorter path, and consequently an increasing proportion of ants will select the path. As fewer ants choose the longer path, and the existing pheromone slowly evaporates, the trail on the longer path will weaken and eventually disappear (Schoonderwoerd et al, 1996).

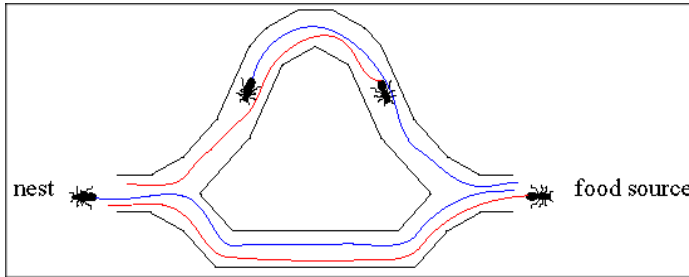


Figure 9. Situation several moments later (Schoonderwoerd et al, 1996, p.7).

It could be remarked that there are two main problems for the ants in play here: the blocking problem and the shortcut problem (Sutton, 1990). The blocking problem occurs when a route previously found by the ants is no longer available. It can then take a relatively long time for the ants to find a new route. The shortcut problem occurs when a new, shorter route suddenly becomes available. In this case the new route will not easily be found, because the old trails are so strong that almost all the ants choose them.

Stigmergy can thus be described as guidance of work performed by social insects through the evidences of work previously accomplished (Wilson 1975). Following White (1997), sematectonic stigmergy is stigmergy where all relevant interaction is done directly through the environment, directly through the field of work (as in the example involving wasps). Again following White, the second type of stigmergy is sign based stigmergy. Here something is deposited in the environment that makes no direct contribution to the task at hand but is used to influence the subsequent behaviour related to the task (as in the example with ants foraging) (White 1997) Again: whether or not it is tenable to designate these “deposits in the environment” signs and whether or not signs cannot contribute directly to the work at hand, as it seems implicitly stated by White (1997), can indeed be debated and we shall do so below in the context of human practice.

We have now introduced the concept of stigmergy and showed that it originates in the study of social insects. We have noted the distinction between sign based and sematectonic stigmergy following White (1997). In contemporary research the concept of stigmergy has, as noted above, been introduced to the field of telecommunication especially in connection with the development of algorithms for

network traffic (these algorithms are termed “ant algorithms”) and to the field of robotics (**Bonabeau** 1999). However, it has not been applied in connection to investigations in the field of CSCW, as far as I am aware. The question for CSCW is, as Susi & Ziemke (2000) points to; can the concept of stigmergy be applied in the description and perhaps even in the explanation of human practice in connection to the articulation of cooperative work through artifacts?

Stigmergy in human coordination practice?

If we leave the world of social insects and return to the world of human beings, we can in part in the following discussion investigate, on a quasi-empirical level, the claim that activity bearing some resemblance to stigmergy, as noted on a purely theoretical level by Susi & Ziemke (2000), can be observed in human practice. We shall take the work of Schmidt and Wagner (2002) as an empirical starting point.

Schmidt and Wagner (2002a) informs us that the work in an architectural office is based on the uses of a large array of artifacts – from sketches, scale models, image, to CAD plans, detail drawings, Excel sheets, and Word documents (Schmidt & Wagner 2002a, p.6). These artifacts serve a number of purposes ranging from representation to ordering and coordination, we shall focus on a particular artifact what Schmidt and Wagner (2002a) term the “the central CAD drawing”. The central CAD drawing can be said to mirror the status and trajectory of a building project as a whole, and is worked on and consulted by the large number of the specialist involved in a building project. Schmidt and Wagner on the CAD drawing:

“The first version is produced at an early stage. As planning progresses the drawing becomes more and more detailed and also specialized, with the different external actors filling in their expertise, which is evaluated and taken into account by the architects. This is a procedure in many loops. It entails numerous design changes. The central CAD drawing witnesses the projects’ trajectory. It absorbs and mirrors the decisions taken and changes made, with the different actors copying versions and layers for different purposes, thereby extracting and adding information” (Schmidt and Wagner 2002b, p.10).

Schmidt and Wagner also observes:

“The CAD plan is the artifact in which all the design decisions that have been worked out in various forms – sketches, calculations, technical descriptions, product specifications, etc. – are recorded and specified. This involves the work not only of the team of architects but of many external specialists. Within the office, people work on different parts and layers of the central CAD plans. Someone responsible for specific tasks such as ‘fire escapes’ may work concurrently on parts/layers used by others. (...). CAD plans cross organizational and professional boundaries many times. The construction engineer, for example, will view, comment and eventually correct the drawings at different stages of the planning process. S/he will receive the relevant layers of the CAD drawing and work on them. Other specialists may receive a print-out and produce their own drawings, which the architects will view, eventually discussing modifications and alternatives. They then may copy these drawings into their CAD plans or draft their version of the specialist’s suggestion. Again others will receive a photocopy of one of the plans and return it with comments, calculations, sketches, etc.” (Schmidt and Wagner 2002a, p.9)

In the absence of a preexisting material field of work (at the planning stage there is no building), architectural representational artifacts (such as CAD drawings) constitute the field of work (Schmidt & Wagner 2002a, p. 14). The specialists (architects, engineers, building constructors etc.) making up the collaborative work ensemble turn to the central CAD drawing, in order to make sense and obtain insight on the progress and details of the building project. In direct alignment to these insights, gained studying the CAD drawing, the individual specialist, conduct his own work of annotation and marking the CAD drawing. In other words: signs left or modifications made by individuals (in this case the various specialists) on artifacts (in this case a set of CAD drawings), feedback on themselves or others: activities (in this case design work) are recorded in the artifact, and this record is used to coordinate collaborative work: collaborative work is coordinated through the evidence of work previously accomplished. It can be noted that this description mirrors Grassés stigmergy concept, as described above, to some extent.

To what extent can we adopt the concept of stigmergy to describe the articulation of cooperate work (in connection with the central CAD drawing?). There are reservations to be made: human beings are not simple creatures of stimuli and response (Bourdieu 1977) and we must be careful not to adopt the stimuli/response model of action in the context of human practice employed by Grassé in the study of social insects. A model of human practice must incorporate notions of meaning,

strategy and structure. As Jenkins (1996) observes: practice, what people do, is bound up with the generation and pursuit of strategies (Jenkins 1996, p.39) employed within the dimensions of space and time, and cannot accordingly be described simply in terms of stimuli and response, as it is done in the case of social insects, whose behaviour have inspired Grassé to formulate the stigmergy concept (Grassé 1959). One important aspect of human practice, including human communication, is time (Bourdieu 1977, Harris 1995). Following Bourdieu, a loyal description of the nature of practice must include the notion that practice is always stretched across time (Bourdieu 1977). Roy Harris (1995) stresses that in every act of human communication there is implicit an integration of past, present and possible future activities. Without this temporal structuring⁷ communication would be an entirely different process, only imaginable in science fiction (Harris 1995, p.38). If human actors do not simply respond to stimuli in their environment, and in contrast can be described as acting to a large extent upon interpretations of their surroundings set in time and space (Bourdieu 1977, Harris 1995). We can, as far as I can see, adopt the stigmergy concept in relation to the description and analysis of human practice. Providing we have clear reservations in regard to the stimuli-response model of action – it does not apply well at all to human practice. Nevertheless, (again as far as I can see) we can adopt the stigmergy notion that work can be coordinated based on evidence of work previously accomplished.

⁷ Regrettably, temporality does not always play a prominent part in scientific analysis. That is not only because the analyst arrives *post festum* as mentioned by Max Weber and cannot be in any uncertainty of what may happen. It is also because the analyst has the time to totalise, to view a phenomenon in its totality (Bourdieu 1977, p.8). The view of the de-temporal analysis is a view from above, a view after the fact. The view of an actor situated in “mundane” practice is in contrast a view situated in time and in the current of time people do not have the time to totalise and are, in contrast to the analyst, in fact to some degree uncertain of what may happen (Bourdieu 1977, p.8). Alfred Schutz also observes:

“We normally have to act and not reflect in order to satisfy the demands of the moment, which it is our task to master, we are not interested in the ‘quest’ for certainty. We are satisfied if we have a fair chance of realizing our purposes, and this chance, so we like to think, we have if we set in motion the same mechanisms of habits, rules and principles which formerly stood the test and which still stand the test” (Schutz, 1943 #1439, p.65).

There seems to be some parallel between what Schutz describes as “mechanism of habits, rules, and principles” and what Bourdieu terms strategies. In the sense that they both emphasis the actors point of view, temporality and the situation of the actor in what is at the same time familiar and unpredictable. Strategies can be described as principles or tested ways of doing things that people consciously and unconsciously employ in order to deal with everyday life (Bourdieu 1977), including their working life.

Further more, we could investigate the temporal aspects of this notion. If we follow Roy Harris (1995) again and hold that in every act of human communication there is implicit an integration of past and present activities (Harris 1995, p.38). We could investigate if stigmergy is more that a question of coordination of work based on work *previously* accomplished. Maybe we could extend Grasse' notion of stigmergy: work can be coordinated based on work previously *and simultaneously*. Consider again the example given Dix (1986):

“Imagine you are moving a large piano. You may say things to each other - “move your end up a bit”, “careful of the step” - but in fact the most important thing is the feel of the other person's movements through the movements of the piano. This sort of communication is effective partly because it is tied so intimately to the work itself, and partly because it is implicit, unconsciously noticed and acted upon” (Dix 1986, p.9).

Considering this an example of stigmergy, it could seem tenable to hold that stigmergy practice can be a question of coordinating work based on work *simultaneously* as well as previously accomplished. Is it not reasonable to describe elements of the movers work as stigmergy taking place simultaneously as well as sequentially? Considering that the movers in relation to one another actually are lifting and manoeuvring at the same time. Under these considerations we could suggest to extended the concept of stigmergy: work can be coordinated based on evidence of work previously and or simultaneously accomplished.

This general notion of stigmergy could to have some potential relevance to the study of cooperative work coordinated through artifacts, but is stigmergy just another term for articulation work?

Is stigmergy articulation work?

Stressing Grasse's original conceptualisation of stigmergy: collaborative work is coordinated through the evidence of work previously accomplished (Grasse 1959). We can perhaps contrast stigmergy to articulation work. Recall the concept of articulation work: all cooperative work practices entail activities that are aimed, in a sense, not so much at the work it self, but at the cooperation – typically: who does

what when. This meta-work is conceptualised as *articulation work*. Cooperative work is articulated in the sense that actors involved in cooperative work must share, allocate, coordinate, mesh, interrelate etc. their distributed individual activities (Schmidt & Bannon 1992, p.14). Compared to the concept of articulation work. Can we hold that stigmergy is *not* articulation work in the sense that stigmergy does not entail what could be considered extra work solely aimed at the coordination? In this view, we are stressing that stigmergy is practice where collaborative work is coordinated through the evidence of work previously accomplished and *not* through meta work aimed solely at the cooperation. In short, stigmergy is not articulation work if we employ this distinction. Consider the following example of the practice of music: Imagine an ensemble playing a piece of music reading the sheets and listening to each other play. Perhaps we can suggest that the collaborative practice of playing a piece of music for several instruments is coordinated on the one hand through the reading of musical notation and on the other hand through listening to the music played. In this view, the case of reading a musical score is *not* stigmergy if we consider the musical score not part of the work itself, but articulation work aimed at coordinating the primary task of making music. Considering just this one example, we could assert that the notion that stigmergy is practice where collaborative work is coordinated through the evidence of work previously accomplished and *not* through articulation work aimed at the cooperation, is depending on a distinction between what is to be considered the primary task (in this case making music) and what is to be considered extra work aimed at the coordination (in this reading the musical notation). Let us take another example: the central CAD drawing (Schmidt & Wagner 2002a), mentioned above, could be considered stigmergy because the work on the drawings can be considered to be the primary task and not articulation work aimed purely at cooperation. In the description and analysis of the practice of the central CAD drawing in the architectural office (Schmidt & Wagner 2002a), it is stated that in the absence of a pre-existing material field of work, architectural drawings constitute the field of work (Schmidt & Wagner 2002a, p.14).

However, the distinction we apply is not without the potential for controversy. Consider the example of stigmergy given above by White et al () i.e. the case of foraging ants laying a trail of hormones to a from the food source. Can we agree with White (1997) and describe this behaviour as stigmergy, if we are to follow our

new found distinction between articulation work and stigmergy? It does not appear so, if we consider food gathering the primary task, then laying the trail of hormones could be described as articulation work⁸, considering that it solely contributes to the food gathering by virtue of coordinating the ant's behaviour. We can notice that in this case, our understanding of the concept of stigmergy differs from Whites (1997).

Resting the distinction between stigmergy and articulation work, on a distinction between coordination of cooperative work through the evidence of work previously accomplished (stigmergy), and coordination of cooperative work through work aimed solely at the cooperation (articulation work), could seem like a tenable position to take, in the view that it makes a relative clear distinction between two forms of coordination of cooperative work through artifacts possible: One the one hand, we have stigmergy where cooperative work on the artifact is coordinated through the evidence of work previously accomplished on the artifact. On the other hand, we have articulation work where meta- or extra work aimed solely at the cooperation is performed through or with artifacts. As an example of the latter we could mention articulation work employing coordinative artifacts such as product standards, blueprints, bulletin boards, clocks, flight deck checklists, maps, procedures drawings etc. (Schmidt 2002, p.33).

At this point it could perhaps be instructive to look at one of these coordinative artifacts and ask the question: is collaborative work coordinated employing drawings, for instance, to be considered articulation work or stigmergy? This question becomes even more relevant when we consider that we have in one instance considered work on drawings stigmergy and in another instance articulation work: one the one hand stigmergy in the case of the central CAD drawing (Schmidt & Wagner 2002a) and on the other hand we included drawings in the list of coordinative artifacts that articulation work can be carried out through (Schmidt 2002). The question is poorly stated of course, in the sense that the nature of the coordinative practice does not spring from any named object. The artifact, named "drawing" and worked on by multiple actors drawing a building for instance, is a different artifact than the

⁸ Please forgive the application of the concept of articulation work on the behavior of insects.

“drawing” used as a template or guide in the process of erecting a building, even if we are talking about the same piece of “paper”.

The arbitrary names we give objects have no connection to what they afford. The fact that a stone can be a missile does not imply that it cannot be other things as well. It can serve as a paperweight, a hammer, or a bookend. It can be piled on top other stones and become a stone wall. To perceive the affordances of an object is not to classify it according to some scheme of names. If you know what an object can be used for, you can call it whatever you like (Gibson 1986, p.134). It is the act of knowing the practices of the artifact that reveals its affordances, we might add. This is emphasized to escape the, in Gibson’s eyes, fruitless exercise of assuming fixed classes of objects, each defined by a common feature and then given a name (Gibson 1986). This could seem to be in accordance with Wittgenstein: you cannot specify the sufficient features of a class of objects to which a shared name is given. In many cases a name can only indicate a “family resemblance” (Wittgenstein 1953; McGinn 1997).

Following Taussig (1993) and the discussion above on the nature of artifacts, we could describe an artifact as a temporal entity constituted both socially and materially and not to be confused with a named object. Following this notion through: in the case of the architectural effort (Schmidt & Wagner 2002a) the drawing as an artifact, not as a named object, is socially constituted in a practice that can be described as stigmergy. Imagine a case of erecting a building on a construction site, the artifact is constituted in a different manner here, it is socially constituted as a reference, as a template, as a coordinative artifact through which the cooperative work of actually raising the building is articulated.

We now have a general notion of stigmergy that is in part distinct and meaningful by virtue of being contrasted and differentiated in relation to the concept of articulation work. However, there is further conceptual work to be done it seems.

Sign based stigmergy and sematectonic stigmergy

Recall that, White (1997) work relies for some part on a distinction between two types of stigmergy⁹: sign based stigmergy and sematectonic stigmergy. Recall that following White (1997), sematectonic stigmergy is stigmergy where all relevant interaction is done directly through the environment, directly through the field of work (as in the example involving wasps). Again following White, sign based stigmergy is when something is deposited in the environment that makes no *direct* contribution to the task, but is used to influence the subsequent behaviour related to the task (as in the example with ants foraging) (White 1997). Whites concept of sign based stigmergy seems to translate into the concept of articulation work we have presented following Schmidt & Bannon (1997). Further more, Whites concept of sematectonic stigmergy seem to bear resemblance of our concept of general stigmergy as we have presented it following Grassé (stigmergy is the practice of work being coordinated based on the evidence of previous work). However, we shall in the following section, discuss Whites distinctions on their own terms.

It could prove useful to employ Whites distinctions and examine whether or not it is tenable: Can the cooperative practice of the central CAD drawing, for instance, most fittingly be described as sign based stigmergy or as sematectonic stigmergy? In the description and analysis of the practice of the central CAD drawing in the architectural office (Schmidt & Wagner 2002a), it is stated that in the absence of a preexisting material field of work, architectural drawings constitute the field of work (Schmidt & Wagner 2002a, p.14). In the case of the CAD drawings, work on them contributes directly to the task and following White (1997) it could consequently be described as sematectonic stigmergy.

Turning to Whites concept of sign based stigmergy, we can recall that following White (1997), sign based stigmergy is when something, which makes *no* direct contribution to the task is deposited in the environment and guides the work at hand (White 1997). We could suggest that the task is relative to the point of view and this is where the utility of White's conceptual distinction could be called into question, considering the case of the central CAD drawing. The work of the central CAD

⁹ See the discussion above.

drawing does not match up with Whites concept of sign based stigmergy, considering that the work *does* in fact contribute directly to the task from the architect's point of view (Schmidt & Wagner 2002a). This could seem counter intuitive since the central CAD drawing is full of annotation and markings that could be described as signs, considering that the annotations and markings are of a representational nature (Schmidt & Wagner 2002a) commonly contributed to signs (Lübcke et al, 1996) - the annotation and markings often represent the finished buildings. It could look like a revision of Whites (1997) distinctions is in order.

White seems to base his distinction between signs and non-signs on the distinction between something that contributes directly to the task (non-signs) and something that does not contribute directly to the task, but guides the cooperative work indirectly (signs). This distinction seems to apply poorly to the case of the central CAD drawing where the task, from the architect's point of view, could be described as an effort to manipulate signs. Alternatively to White (1997) we could employ Wittgenstein's insight that signs are based on conventions (Wittgenstein 1953), and make this proposition the basis of a distinction between sign based stigmergy and sematectonic stigmergy. Wittgenstein convincingly makes the argument that meaning is public, and demonstrates this by showing that the notion of a private language is a contradiction in terms (Wittgenstein 1953, p.243). How is it possible to introduce a private language? Imagine a person A attempting to introduce a private language to describe physical sensation with. A must try to introduce some sign for these sensations. Consider that A notes an "F" every time a certain sensation arises. Considering this it is obvious that A cannot give a public definition of when to apply "F". The question is can A himself understand the meaning of "F"? Does A know what "F" means? Wittgenstein denies that (Wittgenstein 1953, p.371). A can notice that he sometimes writes an "F". He can ask himself if it is correct to do so, but the point is that he cannot be mistaken. A does not have the opportunity to asses if he made a mistake or not. Considering that there are no other rules for the use of "F" other than "F", there are no other designation of the sensation than the sensation it self. There is no possibility to distinguish between correct and faulty use of the sign "F", the concept of correctness only applies in a social context, or a Wittgenstein would put it, in a public context (Wittgenstein 1953). Wittgenstein's assessment of what makes phenomena (an annotation, a sound, a movement) eligible to be designated a sign

plays an important role here. It is not meaningful to speak of signs outside participation in or knowledge of a public practice (Wittgenstein 1953). It could be tempting to hold that “I know this object is the colour red, because I can see it is red”. However, following Wittgenstein (1953), “I know this object is the colour red, because I know the meaning of “red” from my participation in and knowledge of public practice”. Summing up, we can follow Wittgenstein (1953) and state that signs are based on normative conventions (McGinn 1997).

Following Wittgenstein (1953), sign based stigmergy could be considered to be stigmergy where convention fuel the meaning of the traces left by individuals in the environment or on artifacts, these signs may feedback on the individual who made them or on others and trigger new actions. This conceptualisation does *not* rest on a distinction between what contributes directly to the task at hand and what does not, and as such it differs from Whites (1997) distinctions. If we consider the concept of sematectonic stigmergy and continue to follow Wittgenstein (1953), we could consider sematectonic stigmergy to be cases where our experience with the world infuses meaning into modifications made by individuals on the environment (often artifacts), modifications that may feedback on the individual making them or on others and trigger new actions. Again, this conceptualisation does *not* rest on a distinction between what contributes directly to the task at hand and what does not. Following Wittgenstein, The distinction between sign based stigmergy and sematectonic stigmergy is made on the basis of how meaning is created in practice of stigmergy: on the one hand, if the artifacts physical appearance, in the practice of stigmergy, is meaningful as a consequence of conventions, we are dealing with “sign based stigmergy”. On the other hand, if the artifacts physical appearance, in the practice of stigmergy, is meaningful as a consequence of our experience with the world and not as a consequence of conventions, we are dealing with “sematectonic stigmergy”.

Resting our distinction between signs and non-signs on a distinction between conventions (fuelling the meaning of signs) and experience with the world (infusing meaning into marks in the world including marks on artifacts) we have to consider the mediating case of signs that are in some part meaning full as a consequence of conventions and in another part meaning full as a consequence of our experience with

the world. Pierce (1994) gives a name to this branch of signs, namely “iconic-signs”, signs that have an element of being an icon, of actually having some resemblance to what they represent, and in that sense they are not completely arbitrary as other signs are (Pierce 1994, p.109). Pierce (1994) gives as an example of an iconic-sign: the diagram that is meaning full partly as a consequence of its resemblance to what it represents (Pierce 1994, p.104). Pierce theory of signs is surrogational according to Harris (1995); surrogational in the sense that signification is explained in terms of relations between signs and what they stand for (Harris 1995, p.51). The iconic sign bearing resemblance to a house are a surrogate for an actual house in the surrogational approach of Pierce (Harris 1995, p.47). Alternatively, Harris (1995) offers an integrational approach where the sign depends on the context where it is produced; this is an approach that makes no assumption that the sign has any existence outside the communication situation that gave rise to it (we shall return to the topic of integrational semiology below). Harris employs the notion of the “pictorial sign” a sign that is contrasted to the “scriptorial sign” and involves quite different visual and mental processing from recognizing the scriptorial elements (letter form). The recognition of the one does not automatically entail recognition of the other (Harris, 1995 p.48), making sense of pictorial elements does not automatically lead to making sense of letters.

These new found conceptual distinctions could perhaps be clarified with a few examples. An example of sign based stigmergy that comes to mind is the case of the central CAD drawing (Schmidt & Wagner, 2002a). In this case it is partly the conventions of architectural practice and the pictorial nature of some of the signs employed that fuel the traces left by individuals on the CAD drawing with meaning. These signs left by the various building specialists on the CAD drawing may feedback on the individual specialist himself or on other specialists: design work is recorded in the CAD drawing, and this record is used to coordinate collaborative work.

To give an example of sematectonic stigmergy, imagine a team of masons building an arch: The individual mason must carefully lay his bricks in accordance with the work of his fellow masons and in accordance with physical phenomena such as gravity and balance of pressure. The way the bricks are laid by the various individuals may feedback on the individual mason or on his/her colleagues: the

masons work is coordinated through the work it self, and this work is meaningful not as a consequence of conventions but as a consequence of experience with masonry and the world in general, experience not entirely based on convention. It should perhaps be mentioned that it can easily be imagined that sign based practice and non-sign based practice intertwine. In the case of the arch building process, drawings made up of signs as well as experience could well contribute as resources in the process of erecting the brick arch.

At this point we could raise the question of relevance in regard to the distinction between sign based stigmergy and sematectonic stigmergy: is this distinction important to the actor in the fray or, as the case may be, in the monotony of everyday practice? Both stigmergy practices are acquired in one-way or the other, either meaningful through learned conventions or from common experience. Does it matter to the actors if a given phenomena in stigmergy practice is meaningful as a consequence of the one or the other, is it not the point that it is meaningful in the first place? We could regard the distinction to be first and foremost of analytical value and perhaps not a distinction employed by actors in practice. Consider again the following example of the practice of music: Imagine an ensemble playing a piece of music reading the sheets and listening to each other play. Perhaps we can suggest that the collaborative practice of playing a piece of music for several instruments is coordinated on the one hand through the reading of musical notation and on the other hand through listening to the music played. The musical notation is meaningful based on arbitrary conventions while the music makes sense partly through drawing on training and experience¹⁰. It could be noted that listening to the music alone could guide the experienced musicians; they could play by ear alone probably. More commonly though, it is the combination of the musical notation and the listening to the music that coordinates the collaborative effort and helps create music. Is it important to the musicians to distinguish between sign-based practice and non-sign based practice? This is probably a question that can only be answered empirically and not theoretically. Considering that the importance of the distinction to the actors involved may vary considerably across empirical findings.

¹⁰ It is quite debatable whether or not the played music should be considered signs. For the sake of argument we do not do so here.

Summing up, we have made a distinction between articulation work and stigmergy where stigmergy, following Grassé (1959), is practice where collaborative work is coordinated based on the evidence of work previously accomplished and articulation work is, in some sense, the meta work aimed at coordinating a collaborative effort. Further more, following Wittgenstein (1953), The distinction between sign based stigmergy and sematectonic stigmergy is made on the basis of how meaning is created in practices of stigmergy: on the one hand, if the artifacts physical appearance, in the practice of stigmergy, is meaning full as a consequence of conventions, we are dealing with “sign based stigmergy”. On the other hand, if the artifacts physical appearance, in the practice of stigmergy, is meaning full as a consequence of our experience with the world and not as a consequence of arbitrary conventions, we are dealing with “sematectonic stigmergy”. In the above section we ended up with some preliminary concepts:

General stigmergy: signs left or modifications made by individuals on the environment (often artifacts), may feedback on themselves or others, and trigger new actions on the environment or artifact, that in turn may feedback: activities are (partly) recorded in artifacts, and this record is used to coordinate collaborative work: work is coordinated based on evidence of work previously accomplished.

Sematectonic stigmergy: modifications made by individuals on the environment (often artifacts), may feedback on themselves or others, and trigger new actions: activities are (partly) recorded in artifacts, and this record is used to coordinate collaborative work. Or more simply, work is coordinated based on evidence of work previously accomplished and this evidence is meaningful due to common experience with the world.

Sign based stigmergy: signs left by individuals in the environment (often artifacts), may feedback on themselves or others, and trigger new actions: activities are (partly) recorded in artifacts, and this record is used to coordinate collaborative work. Or more simply, work is coordinated based on evidence of work previously accomplished and this evidence is meaningful due to conventions, at least partly considering pictorial signs.

Questions

Let us leave the discussion of the conceptual distinctions for now, and suggest a general notion in connection to coordination of collaborative work through artifacts: signs left or modifications made by individuals on artifacts, feedback on themselves or others: activities are (partly) recorded in artifacts, and this record is used to coordinate collaborative work.

Is this notion not in sync with the concepts of stigmergy and articulation work through artifacts? The act of inscribing or marking¹¹ artifacts could perhaps metaphorically be described as “recording”. While these marks and signs in turn can be described as acting as a “record”, a resource the actors can employ in their coordinative effort.

If we preliminarily accept this notion we can perhaps phrase a series of questions: How does an artifact afford recording? What makes up the record? In what sense is the record used to coordinate collaborative work? These questions will be considered in the following three sections.

How does an artifact afford recording?

As mentioned above, we could ask the question: how does an artifact afford “recording” of activities? Let us consider the case of the central CAD drawing (Schmidt & Wagner 2002a) in an attempt to answer this question. The central CAD drawing is as an artifact and can, following our previous discussion on artifacts, be described as equally social and material phenomena a process rather than a stable entity.

Following Taussig (1993), we could in a preliminary and abstract manner answer the question: an artifact affords the “recording” of activities by virtue of an interplay

¹¹ Here we consider signs to be meaningful due to public conventions while marks are meaningful due to experience with the world, experience not entirely arbitrary. This is following Wittgenstein (1963).

between the real and the real made up, in the case of the central CAD drawing, by virtue of an interplay between materiality and writing system.

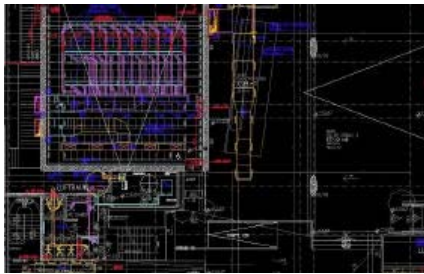


Figure 10. CAD plan with layers (Schmidt & Wagner 2002a)

As far as the material side of the artifact goes, the central CAD drawing is associated with a digital storage and retrieval system and consists of paper printouts of photocopies in A3 format of the drawings, transparent overlays and colour pens (Schmidt and Wagner 2002a, p.6). These components can be said to have affordances Gibson (1986). We could hope that the concept of affordances might point to the role of materiality in artifact-based practices.

The late James J. Gibson coined the concept “affordances” and put emphasis on his belief that more traditional psychologies of the “mind” or of “behaviour” were too narrow in scope: Mentalism, by its belief in the subjective origins of concepts, tend to divorce the “thinking” individual from environmental constraints. Similarly, behaviourism, with its over-reliance on habits not only to describe behaviour but also to explain it, tends to trivialize the acting individual's relation to the environment. Gibson's work and his concept of affordances, on the other hand, recognize the co-evolution of man and his environment and the ever-present reciprocity between the two (Gibson 1986).

A short recent history of the concept of affordances will show that it has roots not least in the gestalt psychology of Koffka (Gibson 1986, p.138). According to Gibson (1986), Koffka (1935) recognized that the meaning of a thing seems to spring from it directly, seems to be perceived just as immediately as its colour: “each thing says what it is ... a fruit says ‘eat me’; thunder says ‘fear me’” (Koffka 1935, p.9). Koffka did not believe that meaning of this sort could be explained within the context of

memory. He believed that things have a “demand character”: the postbox “invites” the mailing of a letter, a door handle “what’s to be grasped” etc. Koffka worked with a distinction between “the physical object” and “the phenomenal object”, the material object and the object in the “mind, and he contributed the “demand character” of a thing to the phenomenal object. Koffka argued that a postbox only has a demand character when the observer needs to mail a letter, not otherwise. The meaning of something was assumed to change as the need of the observer changed (Gibson 1986, p.139).

The concept of affordance is partly derived from the concept of demand character, but with an important difference. 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 is invariant, it is always there to be perceived (Gibson 1986, p.139). Gibson describes the concept of affordances in this way:

“The affordances of the environment are what it offers to the animal, what it provides or furnishes, either for good or for ill. The verb to afford is found in the dictionary, but the noun affordance is not. I have made it up. I mean by it something that refers both the environment and the animal in a way no existing term does. It implies the complementarity of the animal and the environment. “
(Gibson 1986, p.127).

The animal kingdom includes human beings. Affordances have to be accounted for relative to the animal. They are unique to the animal. They are not abstract physical properties they are relative properties of the animal and the environment (Gibson 1986, p.128). Let us consider examples of affordances.

If a terrestrial surface is nearly horizontal (instead of slanted), nearly flat (instead of convex or concave) and sufficiently extended (relative to the size of the animal) and the surface is unyielding (relative to the weight of the animal) the surface affords support. The human species in some cultures has the habit of sitting as opposed to squatting or kneeling. If a surface of support is also knee-high above the ground it affords sitting on. We call it a seat in general, or a chair, stool or a bench. Knee-high is not the same for a child as for an adult, so the affordance is relative to the size of

the individual. If the surface properties are seen relative to the body surface, the self, they constitute a seat and have meaning (Gibson 1986, p. 128).

An affordance, as mentioned, points two ways, to the environment and to the observer. So does the perception that makes up an affordance. Gibson however, stresses that this does not imply separate realms of consciousness and matter. To separate consciousness and matter he rejects as a false psycho/physical dualism. It only implies that to specify the affordances of an object is also to specify the observer himself – to perceive the world is to perceive oneself. The perception of the world and one's complementary relations to the world are inseparable (Gibson 1986, p.141).

Let us take a closer look at how Gibson (1986) deals with the question of meaning. In Gibson own words:

“The theory of affordance is a radical departure from existing theories of value and meaning. It begins with a new definition of what value and meaning *are*. The perceiving of an affordance is not a process of perceiving a value free physical object to which meaning is somehow added in a way that no one has been able to agree upon; it is a process of perceiving a value-rich ecological object” (Gibson 1986, p.140).

Further more:

“There is a ... way of explaining why the values of things seem to be perceived immediately and directly. It is because the affordances of things for an observer are specified in stimulus information. They seem to be perceived directly because they are perceived directly” (Gibson 1986, p.140).

At first sight this could seem rather mystical. How does things have a meaning directly? What does he mean when he states that: “the affordances of something does *not* change, as the need of the observer changes”? Is meaning not a product of the process of making meaning? How does Gibson account for this process? He deliberately does not is seems, he simply states that affordances are there to be perceived directly. However, he does state, for instance, that a postbox affords letter mailing to a letter-writing human *in a community that has a postal system*. We could extend and imagine, at our own peril, that a postbox is only meaningful by virtue of

its place in a system of practices commonly described as a “postal system”. In this view, an actor perceiving the affordances of a postbox does so almost by reflex or directly as Gibson describes it, by virtue of his experience and knowledge of the postal system. The knowledge of the practices of the postal system has become routine, so mundane, that he does not give it a second thought, and perceives the letter-mailing affordance of the box on the road directly¹². Without the practices of the postal system or without the knowledge of the practices of the postal system, the postbox would hardly have the affordances of letter mailing to anyone? Gibson himself, states in describing a postbox that “every one above the age of six knows what it is for and where the nearest one is” (Gibson 1986, p.139). In my view, this implies that a child have to become knowledgeable of the practices of an object in order to be able to perceive its affordances, the affordances or the practices in connection to an object have to be acquired. We could perhaps state then, at our own peril, that the affordances of an object are perceived “directly” by virtue of a familiar routine involving the object. Or as Gibson states: the affordances are relative to the observer (and, we might add, the practices of the observer).

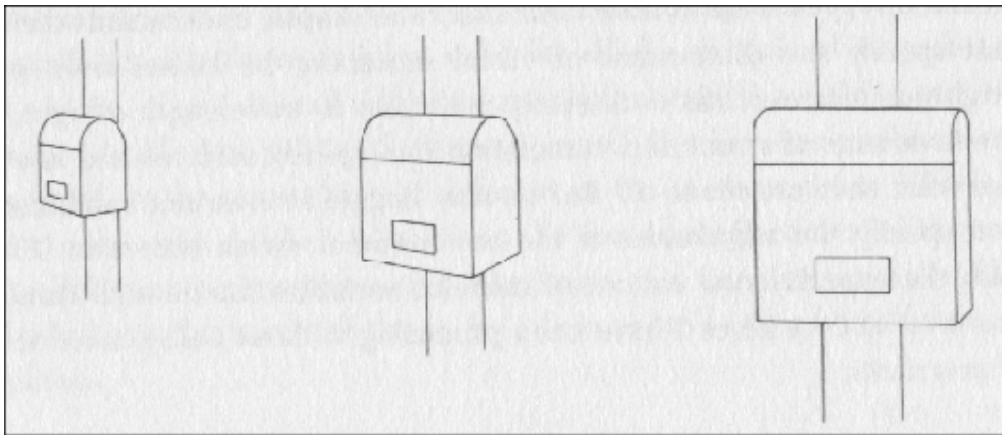


Figure 11. A postbox perceived (Gibson 1986, p.139).

Common practice, routine, or habit as aspects of the meaning of everyday things could point to Schutz (1953) and his notion of the ‘natural attitude’ and suggest that the meaning of artifacts is often be taken for granted in established practices (but other perspectives can be brought into play): an actor in the natural attitude will not

¹² Please note that this explanation is on my account, don’t blame Gibson (1986).

take the infinite number of possible perspectives, points of view, or levels of abstractions into consideration, before acting:

“He takes it for granted that his fellow-man will understand his thought if expressed in plain language and will answer accordingly, without wondering how this miraculous performance may be explained. Furthermore, he does not search for the truth and does not quest for certainty. All he wants is information on likelihood and insight into the chances or risks which the situation at hand entails for the outcome of his actions” (Schutz, 1944).

Following Schutz (1953), the actor does not commonly reflect on the meaning of a well-known artifact, only if something prompts him to change attitude does he change perspective on the objects at hand. Following Schutz (1953) we can suggest that the meaning of an object is observed at first glance ‘in the natural attitude’ and only if the situation requires extra reflection does other qualities spring to mind. Take for example a corkscrew; common to the natural attitude we could perhaps suggest that a corkscrew affords the removal of corks in bottles, the meaning of a corkscrew is to remove corks in bottles? Unless there are reasonable reasons to investigate the artifact at a different level of abstraction, an actor will stick to those perspectives and levels of abstractions that are relevant to his or her routines (Schutz 1953). Reasonable reasons could arise however, and the corkscrew could be considered at a different level of abstraction and perhaps be considered in one reflective attitude a ‘symbol of a certain lifestyle’. The point is that meaning ‘in the natural attitude’ is made at a glance, no reflection is in play. Reflection however, can be brought into play if the situation demands it. If we accept a theoretical ‘kinship’ of sorts between Gibson (1986) and Schutz (1953) here, it could perhaps go a long way to explain how the affordances of things can be said to be perceived directly: we could suggest that it is done in accordance with the routines of the actors in their natural attitude.

Consider Gibson’s (1986) claim that the affordances of something does *not* change, as the need of the observer changes (Gibson 1986, p.138). This notion could at first remain hard to comprehend, especially in the context of Schutz (1953) concept of the natural attitude. A concept based, we might suggest, for some part on the notion of several ‘attitudes’: natural and reflective ones? Consider again the example with the corkscrew, the meaning of the corkscrew changed from ‘bottle opener’ to ‘symbol

of a lifestyle' as the attitude of the observer changed we suggested. Does this mean that the affordance of the corkscrew changed from 'bottle opener' to "symbol of a lifestyle"? Recall that an affordance, as mentioned above, points two ways, to the environment and to the observer. So does the perception that makes up an affordance (Gibson 1986). Perhaps the corkscrew's ability to act as a 'symbol of a certain lifestyle' cannot tenably be considered an affordance, but can perhaps be considered a phenomenon of a different order, considering that its symbolic value has no direct connection to its materiality. Perhaps Gibson when he states that "the affordances of something does *not* change, as the need of the observer changes" is pointing to the importance of materiality to his concept of affordances? We could follow Gibson (1986) and suggest that the affordance of something does *not* change, as the need of the observer changes (and add) in the sense that the materiality of the object is not simply a question of attitude; it remains the same across frames of mind, in the sense that cold steel, for instance, is still hard no matter how you think of it. Perhaps this emphasis is a crucial one if we are to escape mentalism? Can we risk to lose materiality from sight and simply state that frames of mind dictate the affordances of artifacts? Have we then not lost sight of the importance of materiality? When Gibson stresses that the affordances of something does *not* change, as the need of the observer changes, we could perhaps interpret this as an effort to escape the notion that affordances can somehow freely be ascribed to objects. It could be seen as an attempt on Gibson's part to stress that the affordances of objects are *not* solely a matter of subjective effort they are also a matter of materiality. This is of course entirely speculative, and whether Gibson would have agreed or not on this attempt to describe his motives is very debatable indeed.

We could for our part, explain the affordances of an artifact as a product or consequence of the public practice it is part of, **these practices are in turn dependant on the material nature of the artifact**. An artifact, following and expanding on Taussig (1993), is precisely an intertwined material and non-material practice¹³. It is important to acknowledge that social practice is **always** under material constraints and affordances. To give emphasis to the material constraints and

¹³ I fully agree with Gibson (1986) that the persistent dualism of the material/mental, of the physical/psychological, is *not* very productive, and must be transcended at all cost, if we are to understand our world more clearly.

affordances of man. Gibson gives an account how man has changed the face of the earth, in order to change what it affords him, but at the same time no matter how powerful men become they are never going to alter the facts of air, water – the lithosphere, the atmosphere and the hydrosphere. We cannot change it. We all fit into the substructures of the environment in our various ways, for we are all, in fact, formed by them (Gibson 1986): we create the world we live in to the extent of our capabilities and this creation, to some extent our own, creates us in the sense that it serve as forceful living constrains and affordances. We are animals adapting to and creating our ecology.

Gibson's concept of affordances can perhaps give us a tool, a way to conceptualise the importance of the physical properties of an artifact, while at the same time retaining that the meaning or affordances of these physical features are relative to the practices they are part of, or as Gibson states, the affordances are relative to the observer (and we might add, the practices of the observer).

A tentative listing of the affordances of the various components of the central CAD drawing, relative to the actors in the architectural office, can be attempted: The overlays afford seeing through; they afford bending, and the absorption of ink. Blank overlays are often placed over paper printouts and used to experiment with design ideas (Schmidt & Wagner 2002a, p.10). The paper copies and printouts have the affordances of paper, on account of paper being light, thin, flexible and so on, that Sellen & Harper (2001) observe. These affordances include: grasping, carrying, folding, spreading out and ink absorption¹⁴ (Sellen & Harper 2001, p.17). The colour pens afford holding and the secretion of ink. These material affordances are connected to the nature of the writing system applied, as we shall see.

¹⁴ Sellen & Harper (2001) goes on to describe how these affordances allows several practices: jointly viewing and marking while in discussion, reading across many documents at the same time, the physical presence of paper used as a reminder (Sellen & Harper 2001, p.150).



Figure 12. Layered artifacts (Schmidt & Wagner 2002a)

Harris (1995) urges that writing systems should be differentiated on the basis of how they utilize the graphical space available and not on the basis of a distinction such as glottic writing vs. non-glottic writing¹⁵ (Harris 1995, p.63). Harris observes that the writing system can be said to be adapted to the nature of the surface upon which is being inscribed:

“The use of wax tablets in ancient Rome, baked clay in Babylon, pattra in India, tortoise shell in China, is not unrelated to the form of some of the scripts developed in those regions” (Harris 1995, p. 30).

In the same vein we can note that the writing system employed on the CAD drawing is probably not unrelated to the surface being inscribed. Further more, Harris states that a writing system exists as a set of practices associated with an inventory of written form. Acquaintance with such practices is often explicitly thought in educational curricula (Harris 1995, p.56), on an architectural training academy for instance, and it is knowledge of these practices that make up the writing system, that in part make an actor competent in the setting of the architectural office for example. The writing system applied to the central CAD drawing can be described as one such set of practices as noted by Schmidt & Wagner (Schmidt & Wagner 2002a), we shall return to these practices below.

Summing up, we can note following Harris, that there exists a non-arbitrary relationship between writing system and materiality, and in a preliminary manner

¹⁵ Glottic writing can be said to mirrors the spoken language in contrast to mathematical notation or a music score that does not do so.

state that this relationship can be described as constituting what affords the artifact to record activities in cases of sign based articulation work.

What makes up the record?

If we accept that activities are (partly) recorded in artifacts, and this record is used to coordinate collaborative work, we are able to ask the question: what makes up the record? A preliminary answer could perhaps be: “information”.

The scientific formulation of the concept of “information” can be traced back to the “mathematical theory of communication” developed shortly after World War 2 by Claude E. Shannon for the purpose of measuring the transportation capacities of communication networks (Shannon 1948, p.379). Of course, the word “information” was in common usage for many years before its scientific conceptualisation. It was recorded in print in 1390 to mean “communication” or “knowledge” or “news” of some fact or occurrence (Oxford English Dictionary). However, as a part of his mathematical theory of communication Shannon coined a definition of information that transformed it into a physical parameter capable of quantification. He accomplished this by separating information and meaning. He applied “meaning” for the semantic part of a message and used “information” to refer to the *quantity* of different possible messages that could be carried along a channel of communication at any one time depending on the message’s length and on the number of choices of symbols for transmission at each point in time (Aspray 1985, p.119). For his purpose this was quite appropriate because as Shannon stated: *semantic aspects of communication are irrelevant to the engineering problem* (Shannon 1948, p.379). Shannon had coined a quantitative concept to be used for measuring and emphasized that “information” must not be confused with “meaning” (Shannon & Weaver 1949, p.8). Sadly however, it has been observed how derivatives of Shannon’s quantitative concept of information have been correlated with meaning in a quite confusing manner in the cognitive sciences. Schmidt (2002) observes how the “information processing” paradigm is based on using the concept of information in the sense of the volume of an arrangement of signs and at the same time the meaning of these signs. The concept of information is being used as a term for the arrangement of signs as well as there meaning in a particular community in a certain situation (Schmidt 2002,

p.15). It is by these means that some branches of cognitive science has been able to reduce human understanding to a quantitative measure (by confusing meaning and measure), and have created paradigms such as the “information processing” paradigm, whose followers are preoccupied with the measure of how much information a person can “compute” at any one time. Aiming to fix the boundaries of rationality in quantitative terms, equating the boundaries of rationality with a measure of processing capacity. Herbert Simons one of the main proponents of the information processing paradigm states:

“The point of departure is the observation that human thinking powers are very modest when compared with the complexities of the environments in which human beings live. If computational powers were unlimited, a person would simply consult his or her preferences (utility functions) and choose the course of action that would yield maximum utility under the given circumstances. That is, of course, just what the “rational man” of classical economic theory does. But real human beings, of bounded rationality, cannot follow this procedure. Faced with complexity and uncertainty, lacking the wits to optimise, they must be content to satisfice—to find “good enough” solutions to their problems and “good enough” courses of action” (Simon 1979, p. 3).

However, it has been pointed out that the boundaries of rationality should not be found in any quantitative form, but elsewhere in a condition of epistemological nature: the world cannot be exhaustively described; there is always another level of granularity, another perspective, another level of abstraction to considered (Schmidt 2002, p.13). In this view, it is this epistemological condition and not a quantitative measure that constitute the boundaries of rationality.

Given the history of the scientific concept of information it could look like the answer to our question: “what makes up the record of artifacts?” Should not be answered with: “information”. This answer would hardly bring about any clarity or better understanding of the problems at hand, because what are we taking about? A quantitative measure, meaning or both?

Never the less, we can observe that Hutchins & Klausen (1996), also quote above, conceptualise what is ‘represented in the physical setting of a device’ as information:

“We can see that the information moved through the system as a sequence of representational states in representational media. From speech channel to internal memories, back to speech channels, to the physical setting of a device” (Hutchins & Klausen 1996, pp.27).

Information seems to migrate unchanged from mind to artifact to mind, maintaining unity and identity (Schmidt 2002, p.3) across materiality, minds and time¹⁶ in Hutchins & Klausens view. This approach has been seen as having some resemblance to what Harris (1995) describe as “telementational” (Schmidt & Wagner 2002a). The telementational approach has its roots in the premises of communication set up by Ferdinand de Saussure (Harris 1995, p. 21): Saussure envisages two individuals (A and B) attempting to resolve the problem of transferring a thought already formulated in the one mind (that of A) to another mind (that of B). Communication is achieved if the thought in B’s mind is indeed the thought A’s mind formulated (Harris 1995), and it can be added that Saussure offers no account of “partial” or “incomplete” communication (Harris 1995, p.21).

Roy Harris propose a radical alternative to the telementational approach, he offers to take up the study of signs where Saussure left off. He offers the “integrational” approach, based on premises, which are different from those of Saussure (Harris 1995, p.5). In Saussurean semiology there is no room for the single, isolated sign. The sign only exist in terms of being a part of a system of signs, and are consequently defined solely by reference to the system as a whole. The relational system is at the same time what guarantees the invariance of the signs. By contrast, in integrational semiology the sign does not exist outside the (social) context which gives rise to it: there is not abstract invariant that remains “the same” from one context to the next (Harris 1995, p.22). Roy Harris gives an example to clarify his position:

“In every day parlance the word *sign* often refers to a physical object, as for instance in the Highway Code to place a ‘red warning sign’ (a reflecting triangle) on the road at least 50 meters in front of a vehicle that has broken down.¹⁷ This use of the word *sign* is a potential source of confusion. For the integrational theorist, the reflecting triangle does not become a sign until it is

¹⁶ It can be helpful briefly to consider the history of the concept of information in order to observe how meaning and information became ‘strangers’, and how this understanding of the concept diffused into the sciences. The word information was in common usage for many years before its scientific conceptualisation. It was recorded in print as far back as the year 1390 to mean knowledge, news or some fact or occurrence (Aspray 1985, p.117).

¹⁷ *The Highway Code*, rev. edn (London: HMSO, 1987), art. 133.

appropriately placed in a situation of the kind described. The same physical object – the red triangle – was not a sign during the time it remained in the boot of the motorist’s car in readiness for such an emergency; nor having once functioned as a sign, it will continue to do so when the motorist eventually puts it back in the boot again and proceeds on the journey. The spatio-temporal continuity of the object is irrelevant to its semiological role” (Harris 1995 p.53).

In the integrational approach the sign only exist in the situation that give rise to it, as a contrast the telementational approach views the sign as a stable entity (Harris 1995). The understanding of the sign as a stable entity (the telementational approach) can lead to a certain view we can imagine, namely that artifacts somehow holds signs or information: a person formulates a thought and records it into an artifact as information which another person later receive during his/her use of the artifact. On the other hand there is the integrational approach: an understanding of the sign as only existing in the situation that gives rise to it: the material appearance of the artifact can give rise to signs given an appropriate context. Take for example the central CAD drawing; in the hands of an architect at work, it can give rise to signs of a building. To the architect’s five-year-old boy playing on the floor the same drawing can become a toy, and give rise to signs of dragons and airplanes. The point is that the record is not simply there, the record has to be reproduced on every encounter with the artifact (Harris 1995, Schmidt 2002).

I could look like, the telementational notion that a person formulates a thought and records it into an artifact as information which another person later receive during his/her use of the artifact, is overly simplistic, and takes the practices of reproducing the “information” for granted, as pointed out by Schmidt (Schmidt 2002). Further more, the lack of context sensitivity in the telementational approach, the importance of which is pointed out not least by Nardi (1996) seems to leave the telementational approach short of explaining the importance of the context of a specific practice.

If we should make an attempt at a preliminary answer to the question of ‘what makes up the record of a coordinative artifact?’ the (integrational) answer at hand could be that the record is made up by the actors practice: the practice of actors gives rise to signs based on the material appearance of the artifact. Such practices can in large part be described as writing system as noted above, and the material appearance

of an artifact can often be equated to an inventory of written form: actors in architectural practice give rise to signs of buildings based on the written form of CAD drawings or actors in air traffic practice give rise to signs of navigation based on the written form of their instruments. However, the tangible materiality of the artifact can in some situations serve as more than a surface of inscription, it can serve as a meaningful indication in its own right. Schmidt & Wagner (2002a) observe how a pile of plans marginally positioned on a desk, as opposed to centrally, may indicate that the architect at that desk may have finished working with them but is not quite sure that she will not need them again (Schmidt & Wagner 2002a, p.15). Here the artifact as a whole, and not its written form, give rise to a meaningful indication. Other scenarios where the meaningfulness of the artifact relies on the actors experience with the world and not on the conventions of signs could be imagined.

The notion that the practice of actors gives rise to signs or attribute meaning to marks based on the material appearance of the artifact, could imply that a specific set of practices, in relation to the material appearance of the artifact, to a large extent can be said to make up the record of a coordinative artifact?¹⁸.

This could imply that artifacts do not hold information, signs or meaning in any passive sense. The meaning of the artifacts is not simply there, it has to be created by the actors on every encounter with the artifact. The meaning of signs, in the integrational framework (Harris 1995), and marks on artifacts is relative to a context of practice, and does not exist outside it. This does not necessarily entail that actors make a great effort to make sense of the appearance of artifacts practice can often entail a fair amount of unreflective routine and repetition (Bourdieu 1977). Mostly making sense is effortless to the skilled actor to the novice however it can be a different matter. What is meaningful from the point of view of the individual actor is closely connected to the actor's knowledge and experience with the work setting and ultimately with the world the actor is born into. In making sense of the appearances of artifacts, an actors draws on his/her knowledge of the work setting, the tools, the conventions and concepts, the normal routines and procedures, and ultimately on general culture (Schmidt 2000, s.4). According to this view, an artifact is a temporal

¹⁸ Evidently the overarching cultural- and social setting also infuse into this creation of meaning.

entity in the sense that the meaning associated with the material object is reproduced at every encounter and no more stable than practice it self.

As a brief note on language, using a phrase like “the meaning of the artifact” could lead to the miscomprehension that artifacts are things in a passive and stable sense. Perhaps we should be wary of our use of language, and emphasis what we set out to hold, namely that artifacts are not things but practices or processes of constituting social and material entities in a particular and meaningful way. We could rephrase “the meaning of artifacts” to “the meaning created in the process of constituting the social and material entity we choose to designate an artifact”.

If we press the notion that an artifact is not a thing but a practice or process of constituting a social and material entity in a particular and meaningful way, can we claim that there are as many artifacts as there are actors, even if we are dealing with a single physical entity? Considering that every individual will have to go through the process of constituting the artifact him/her self, and as a consequence of this, the artifact will be constituted a little differently every time? Perspectives always vary due to individual positions in the field of work and personal history (Bourdieu 1977). Following the logic of this argumentation, we could answer: yes, there are in a sense as many artifacts as there are actors, even though we are referring to a single physical entity. This answer could seem unacceptable considering its somewhat counterintuitive nature and perhaps this splitting of hairs is not really of significance. What is important we could claim, is that the individual constitutions of the singular objectified entity (it is objectified due to its materiality) is, in most cases, sufficiently overlapping that it for all practical purposes makes sense to treat it as an artifact in the singular. The homogeneity of dispositions towards constituting a particular artifact, within the limits of a group of collaborating actors in the same circumstances, could perhaps be contributed to the a phenomena Bourdieu (1977) describe as the tendency of actors to internalise the structures of their environment, and in turn externalise these internalisations and reproduce the environment that in turn again is internalised (Bourdieu 1977, p.72). Following Bourdieu (1977), the homogeneity of the dispositions towards constituting artifacts within a group in shared circumstances can perhaps be contributed to the fact that these dispositions can be viewed as internalisations of a shared environment.

Summing up, the notion that the practice of actors gives rise to signs or attribute meaning to marks based on the material appearance of the artifact, could imply that a specific set of practices, in relation to the material appearance of the artifact, to a large extend can be said to make up the record of a coordinative artifact?¹⁹.

In what sense is the record used to coordinate collaborative work?

If we accept that activities are (partly) recorded in artifacts, and this record is used to coordinate collaborative work, we are able to ask the question: in what sense is the record used to coordinate collaborative work? However, at this point in the discussion, as a result of the discussion above, we can attempt to reformulate that question: in what sense can a specific set of practices, in relation to the material appearance of the artifact, coordinate collaborative work?

Following the stigmergy concept and the concept of articulation work, it could in a preliminary manner be stated that actors order the world they inhabit in a foreseeable way in order to create a familiar and predictable environment. This environment in turn disciplines and structures the behaviour of the actors. We could describe actors and the artifacts they employ as participants in a dialectic process: Actors structure the artifacts they employ and the same artifacts in turn feedback on the actor's behaviour in a disciplining and structuring manner:

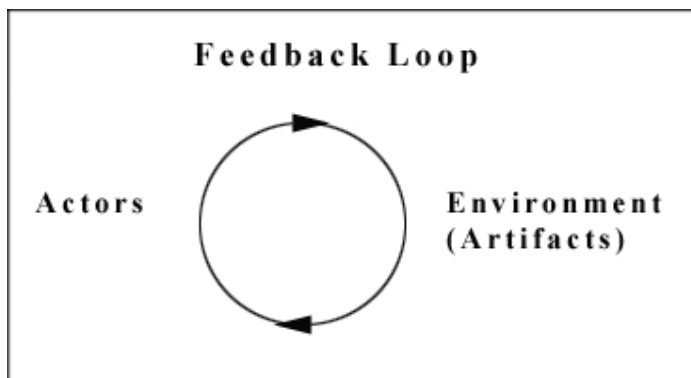


Figure 13. The actor/artifact feedback loop.

¹⁹ Evidently the overarching cultural- and social setting also infuse into this creation of meaning.

To describe the relationship between the individual and his surroundings in terms of the complementary concepts of actor/structure or agency/structure, as we implicitly have done above, can be found among other places in the influential social research of Pierre Bourdieu (Jenkins 1992). Bourdieu (1977) holds that the generation of practice is a dialectic process of internalisation of externality and externalisation of internality, or, more simply, of incorporation and objectification. Structures can according to Bourdieu's brand of sociology: generative structuralism or practice theory, be found on two levels, on the one hand in the individual and on the other hand in the individual's social and material environment. The objective or external social and material conditions of existence produce a structure internal to the individual, that the individual in turn lives by and structures his social and material conditions of existence with (Bourdieu 1977, p.72). This feedback or dialectic process between the internal and the external, where the dual levels of structure mirror and reproduce each other, can also, we could suggest, be an apt description in relation to collaborative work practice coordinated through artifacts. Can we describe the process in the following way: actors structure the artifacts (artifacts are part of the objectified structures external to the actor) they employ and the same artifacts in turn feedback on the actor's behaviour in a disciplining and structuring manner (the actor internalises the objectified or external structures of his environment that artifacts are a part of)? If we accept that, to what degree then is the actor determined in his/her activity by these external structures that he or she internalises? The objectified structures in turn internalised by the actors shape practice in a non-mechanical way according to Bourdieu (1977), but that does not mean that they do not shape practice (Bourdieu 1977, p.73). In the words of Bourdieu (1977):

“... Rejection of mechanistic theories in no way implies that, in accordance with another obligatory opinion, we should bestow on some creative free will the free and wilful power to constitute, on the instant, the meaning of the situation ...” (Bourdieu 1977, p.73).

In the eyes of Bourdieu (1977), individuals do not, strictly speaking, know what they are doing, in the sense that what they are doing has more meaning than they know. The internalised structures remain obscure to their producers, the individuals that produce them, it is not possible for an individual to totalise the external social and material conditions of existence that affects him, conditions which he internalises and

lives by (Bourdieu 1977, p.79). This could imply that actors cannot themselves fully give account of their own practices in relation to articulation of cooperative work through artifacts, in the sense that they do not fully comprehend the internalised structures they act in accordance with. This phenomenon could give rise and be seen as having some resemblance to, as far as I can see, what is sometimes referred to as “tacit knowledge²⁰”. “The actors own account of their practice is not an explanation of their practice, it is part of what needs to be explained by the sociologist”, Bourdieu states in a textbook written for sociology undergraduates (Bourdieu et al. 1991).

Further more, in the words of Marx in the *Economic and Philosophical Manuscripts*:

“If I have no money for travel, I have no need, i.e. no real self realizing need, to travel. If I have a vocation to study, but no money for it, I have no vocation to study, i.e. no real, true vocation.”

Because, and this is according to Bourdieu (1977), the internalised objective conditions of existence engender aspiration and practices compatible with those objective or external conditions of existence. The most improbable practices are excluded, either totally or without examination, as *unthinkable*, or actors become inclined to make a virtue of necessity, that is, to refuse what is anyway refused and to love the inevitable (Bourdieu 1977, p.77). This could imply that artifacts in cooperative work practice for some part, large or small depending on the situation, constitute the horizon of possibilities and impossibilities. The individual artifact has a certain constitution of a social and material nature that can inspire and accommodate certain practices while rendering others impossible. The central CAD drawing (Schmidt & Wagner 2002a) for instance, could be described as accommodating sign based practices of modelling buildings in two dimensions, while other ways of modelling buildings are not supported and are therefore impossible to carry out or impossible even to imagine: Tangible three dimensional models are not supported by the CAD drawing for instance²¹ (only the illusion of three dimensions is, considering that the screen or paper is flat) while other modes of representation remain unthinkable (it would be a contradiction in terms to think up and give an example of the unthinkable, would it not?). We could imagine, that it is not solely a question of artifacts affording various practices, it is also a question of artifacts shaping the space

²⁰ On tacit knowledge see for example Crowley (2001)

²¹ Other practices and artifacts accommodate this kind of representation.

of possibilities in such a forceful manner, that alternatives become hard to imagine, actors become inclined to make a virtue of necessity and refuse what is not afforded by the artifacts, as not being desirable, or to write it off as unproductive “dreaming”.

Further more, recalling the concept of coordinative artifacts coined by Schmidt & Simone (1996), structures internal to artifacts, can take the form of formal constructs and influence the actions of cooperative actors in a strong or a weak sense: formal constructs associated with or internal to artifacts can act as maps or scripts depending on the situation:

“They may, on one hand, as suggested by Suchman and others, play the weak role of the ‘map’ of the traveller that offers a codified representation of salient features of past and future actions which actors may consult as a referent. On the other hand, however, they may play the strong role of a ‘script’ that offers a precomputation of interdependencies among activities (options, required actions, sequential and temporal constraints, etc.) which, at critical points, provides instructions to actors of possible or required next steps” (Schmidt 1997, p.144).

While the notion of formal constructs, or protocols in Schmidt & Simone (1996) terms, that stipulate the articulation of cooperative work is crucial to the concept of coordinative artifacts, it could be contested, as Schmidt (1997) is well aware. In parts of the sociological literature, the idea of pre-defined organisational constructs (plans, methods, formal structures) as determinants of actors practice has been criticised (Schmidt & Simone 1996, p.166). These parts of the sociological literature have convincingly showed that these formal constructs in relation to representing actual practice are not adequate and can even be considered to be misrepresentations of practice in a sense. In the words of Philip Selznick:

“The formal administrative design can never adequately or fully reflect the concrete organization to which it refers, for the obvious reasons that no abstract plan or pattern can – or may, if it is to be considered useful – exhaustively describe an empirical totality” (Selznick 1948, p.25).

Quite some years later Suchman and Wynn, studying office procedures, came to conclusions along similar lines: the effort involved in accomplishing office tasks is ignored in formal descriptions of the work, and states that: “The point of this observation is not to critique procedural formulations, but to indicate *another domain*

of the work, in which those formulations are brought to bear on the practical contingencies of actual tasks” (Suchman & Wynn 1984, p.139). Later Suchman in her influential book *Plans and Situated Action* (1987) comes to propose a metaphor for the way “these formulations are brought to bear on the actual tasks”, namely that of a map:

“Just as it would seem absurd to claim that a map in some strong sense controlled the traveller’s movements through the world, it is wrong to imagine plans as controlling actions. On the other hand, the question of how a map is produced for specific purposes, how in any actual instance it is interpreted *vis-à-vis* the world, and how its use is a resource for traversing the world, is a reasonable and productive one” (Suchman 1987, p.188).

Suchman comes to the conclusion that constructs of a formal nature cannot determinate action causally instead they serve as maps which competent actors can use as guidelines and resources in their practice. However, in several places Suchman makes more general and radical suggestions: “the procedural structure of organizational activities is the *product* of the orderly work of the office, rather than the reflection of some enduring structure that stands behind that work” (Suchman 1987 p. 321). Suchman suggests that formal procedures are used by actors in their practice as a general reference of orientation, and does not or cannot prescribe sequences of action. This interpretation of the status of formal constructs in cooperative practice is challenged by Schmidt in his article “Of maps and scripts – the status of formal constructs in cooperative work” (Schmidt 1997). Schmidt criticizes Suchman for overly generalising on the basis of a single empirical study of office work and brings more nuances into the debate on the status of formal constructs in cooperative work. He suggests that formal constructs such as coordinative protocols play very different roles in cooperative work:

“They may, on one hand, as suggested by Suchman and others, play the weak role of the ‘map’ of the traveller that offers a codified representation of salient features of past and future actions which actors may consult as a referent. On the other hand, however, they may play the strong role of a ‘script’ that offers a precomputation of interdependencies among activities (options, required actions, sequential and temporal constraints, etc.) which, at critical points, provides instructions to actors of possible or required next steps” (Schmidt 1997, p.144).

Schmidt suggest to consider formal constructs such as coordinative protocols to be not casual determinants of practice (here he is in line with Suchman) but rather normative constructs that influence or mediate practice in a strong sense (as a script) or in a weaker sense (as a map) dependent on the circumstances (Schmidt 1997). As an example of formal construct that can be described as a script Schmidt offers the check list as it is used in safety critical situation for instance in air traffic (Schmidt 1997, p.142).

We can, on the basis of the discussion on the status of formal constructs in cooperative work and on the basis of the concept of coordinative artifacts, follow Schmidt (1997) and observe that the coordinative protocol found in the practices of coordinative artifacts, does not determinate cooperative work in a casual sense but act as maps or scripts to be followed by the competent actor in a normative sense.

Further more following Bourdieu (1977), we could add on the subject of the nature of agency that actors manoeuvre by projecting the "negative freedom" the space of possibilities, into quasi-conscious calculations of "things to do or not to do". This could take the form of plotting or strategy making, where chances and outcomes are quasi-consciously perceived on the basis of objectified structures internalised by the individual. Unlike the estimation of probability which science constructs with rigor and method on the basis of precise data established according to precise rules, practical evaluation of the likelihood of success for a given action in a given situation brings into play a whole body of sayings, common sense, wisdoms, normative constructs ("that is not how we do things here") that on a structural level can be described as the regularities (internalised by individuals: experienced through a long working life and or learned in training) that determine what is "reasonable" and "unreasonable" action. Artifacts in cooperative work practice, the nature of their social and material constitution contributes to the above-mentioned regularities. It must be emphasized that not only artifacts contribute to these structures, macro social phenomenon (issues of economy, ethics, religion, power, gender, race, status etc.) are major forms of these structures, overarching the more locally constituted regularities, such as the ones commonly associated with or internal to artifacts²².

²² In other words, artifacts are part of the structured structures that structure action.

Summing up, we can suggest that actors structure the artifacts they employ and the same artifacts in turn feedback on the actor's behaviour in a disciplining and structuring manner.

Perspectives and retrospect

How is cooperative work coordinated through artifacts? This question was the point of departure for this thesis. Along the way of getting closer to an answer we investigated the nature of artifacts and several modes of coordinative practice based on them.

Concerning the line of enquiry we could perhaps in retrospect suggest that the references chosen seem to hold a common emphasis on process, practice, materiality, context and the temporal and impermanent nature of meaning (Taussig 1993, Bourdieu 1977, Harris 1995, Schutz 1953, Gibson 1986, Schmidt 1997 and Wittgenstein 1953). Further more, these references could seem to reject essentialism and for some part mentalism²³.

Following these leads we suggested that artifacts could be described as being constituted by actors between the real and the real made up. We suggested that artifacts are temporal entities of a social and material nature that feed of the practices they are part of in order to arise not only as meaningful but to arise at all: we

²³ Lets consider a few examples: Bourdieu's (1995) concept of practice emphasise the temporal creation of meaning and structure, that is reproduced by the very performance of practice, meaning and structure is not simply there it must be created and recreated. Another example of the emphasis on context and practice could be the integrational approach of Harris (1995). Harris (1995) stated that the sign only exist in the situation that give rise to it, the sign only exist in a temporal context of practice and there can be no essential meaning to the sign. According to Wittgenstein (1953) language is based on conventions, we could suggest to view conventions as routines of practice. In this view there is no essential meaning of words, the meaning of a word is in its context of use, in the context of conventions reproduced in practice.. Following Gibson (1986) we stated that the affordances of artifacts are relative to the observer and to the practices of the observer: the affordances of artifacts are not essential but rather relational in nature. Further more, employing Taussig (1993) we grounded the enquiry in an ontology designed to consider the material as well as the non-material conditions of existence in a form that underline the inseparability of the two: we live between the real and the real made up. This could be considered to echo Gibson (1986) notion that the persistent dualism of the material/mental, of the physical/psychological, is not very productive, and must be transcended, if we are to understand our world more clearly. All these references seem to emphasise, we could suggest, context and practice as being key to the creation of meaning.

suggested that the creation of the artifact and the creation of its meaning cannot tenably be considered apart, it could be considered to be the same process.

Concerning concepts for the description and explanation of coordination of cooperative work through artifacts, we noted two distinct candidates: stigmergy and articulation work. On the one hand, we have stigmergy (Grassé 1959) where cooperative work on artifacts is coordinated through the evidence of work previously or simultaneously accomplished on the artifact. On the other hand, we have articulation work (Schmidt & Simone, 1997) where meta- or extra work aimed solely at the cooperation is performed through or with artifacts.

With the concepts of stigmergy and articulation work in mind, we could perhaps attempt to answer the question we set out to investigate, namely, how cooperative work can be coordinated through artifacts? Our preliminary answer could perhaps be: cooperative work can be coordinated through artifacts in practices of stigmergy and articulation work: signs left or modifications made by individuals on artifacts, feedback on themselves or others: activities are (partly) recorded in artifacts (in the form of signs and modifications to artifacts) and this record is used to coordinate collaborative work. This answer is of course open to debate.

Turning to the design implications of our inquiry we could perhaps suggest that we are not designing things when we are designing (digital) artifacts for the support of cooperative work, we are designing social and material practices. Along these lines, we could suggest that the successful design of digital artifacts for the support of cooperative work is at least equally dependant on the design of practices as on, for instance, the design of electronic circuits. This perspective could, for instance, be applied to the fields of ubiquitous and pervasive computing in connection to CSCW (and possibly other fields as well).

Looking ahead, we could note that it could perhaps be of interest to explore the concepts of stigmergy and articulation work in relation to ubiquitous computing, with the purpose of informing the design of computer support for cooperative work.

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Bibliography

Aspray, William. 1985: "The Scientific Conceptualization of Information: A Survey," *Annals of the History of Computing* 7:2: 117-140

Beckers R, J. L. Deneubourg, and S. Goss. 1992 : Trails and U-turns in the selection of the shortest path by the ant *Lasius Niger*, *Journal of Theoretical Biology*, 159, 397-415.

Beigl, Michael; Tobias Zimmer and Christian Decker. 2002: "A location model for communication and processing of context," *Personal and Ubiquitous Computing*, vol. 6, no. 5-6, p. 341-357.

Bernstein, Richard J. 1983: *Beyond Objectivism and Relativism: Science, Hermeneutics and Praxis*. Oxford: Basil Blackwell.

Bonabeau, E and M. Dorigo, and G. Theraulaz. 1999: *Swarm Intelligence: From Natural to Artificial Systems*. New York, Oxford University Press.

Bourdieu, Pierre 1977: "*Outline of a Theory of Practice*", Cambridge University Press, Cambridge.

Bourdieu, Pierre, Jean-Claude Chamboredon and Jean-Claude Passeron. 1991: *The Craft of Sociology – Epistemological Preliminaries*. De Gruyter. New York.

Denzin, Norman K. 1997: "*Interpretive Ethnography – Ethnographic Practices for the 21st Century*". London: Sage.

Dix, Alan. 1996: "*Challenges and Perspectives for Cooperative Work on the Web*". In: Proceedings of the ERCIM workshop on CSCW and the Web. Sankt Augustin, Germany.

Gibson, J.J. 1986: *The Ecological Approach to Visual Perception*, New Jersey & London, Lawrence Earlbaum Associates, (originally published in 1979).

Grassé, P.P. 1959: "*La reconstruction du nid et les coordinations inter-individuelles chez *Bellicositermes natalensis* et *Cubitermes* sp. La théorie de la stigmergie: Essai d'interprétation des termites constructeurs*," *Insect Sociaux*, vol. 6, pp. 41--83.

Halverson, C. 2002: Activity Theory and Distributed Cognition: Or What Does CSCW Need to DO with Theories? Computer Supported Cooperative Work 11(1-2): 243-267.

Harper R.H.R and John A. Hughes. 1993: What a f-ing system! *send 'em all to the same place and then expect us to stop them hitting: Making technology work in air traffic control*. In Graham Button, editor, *Technology in Working Order: Studies of work, interaction, and technology*, chapter 7, pages 127--144. Routledge.

Harper, Richard R., John A. Hughes and Dan Z. Shapiro. 1989: *The Functionality of Flight Strips in ATC Work*. The report for the Civil Aviation Authority, Lancaster Sociotechnics Group, Department of Sociology, Lancaster University.

Harper, R., Hughes, J. A., Shapiro, D. Z. 1991: '*Working in harmony: An examination of computer technology in air traffic control*', In *Studies in Computer Supported Cooperative Work. Theory, Practice and Design*, eds J. M. Bowers and S. D. Benford, Amsterdam: North-Holland.

Heath, C. & Luff, P. 1991: *Collaborative Activity and Technological Design: Task Coordination in the London Underground Control Rooms*. In Proceedings of ECSCW'91, The European Conference on Computer-Supported Cooperative Work. Kluwer Press.

Heath Christian C and Paul Luff. 1992: "Collaboration and control: Crisis management and multimedia technology in London Underground control rooms," *Computer Supported Cooperative Work (CSCW) An International Journal*, vol 1. no 1-2, pp. 69 – 94.

Harris, Roy. 1995: *Signs of Writing*, Routledge, *London and New York*.

Hirst, Paul. 1985: "Is it rational to reject relativism?" in: Overing (ed.) *Reason and Morality*. London: Tavistock Publications, p.85-103.

Hollan J., Hutchins E., and Kirsh, D. 2000: *Distributed cognition: toward a new foundation for humancomputer interaction research*, *ACM Trans. on Computer-Human Interaction*, 7(2).

Hughes, John, Dave Randall, and Dan Shapiro. 1991: "*CSCW: Discipline or Paradigm? A sociological perspective*," in ECSCW '91. *Proceedings of the Second European Conference on ComputerSupported Cooperative Work*, edited by L. Bannon, M. Robinson and K. Schmidt, Kluwer Academic Publishers, Amsterdam, pp. 309-323.

Hutchins, E. 1995: *Cognition in the wild*, Cambridge, MA: The MIT Press.

Hutchins, E and T. Klausen. 1996: *Distributed cognition in an airline cockpit*. *Cognition in communication at work*. Eds. Y. Engeström and D. Middleton (eds): *Cognition and Communication at work*, Cambridge University Press, Cambridge 1996, pp. 15 - 34.

Jenkins, Richard. 1992: *Pierre Bourdieu*. Routledge, London and New York.

Kaptelinin, V & K. Kuutti, and L. Bannon. 1995: *Activity theory: Basic concepts and applications*. *Lecture Notes in Computer Science*, 1015:189-?

Kaptelinin, V. 1996: *Activity Theory: Implications for Human-Computer Interaction*. In Nardi BA (ed.) *Context and Consciousness. Activity Theory and Human-Computer Interaction*. The MIT Press, Cambridge, pp. 103-116.

Koffka, K. 1935: *Principles of Gestalt Psychology*. New York: Harcourt, Brace & World

Kuutti, K. 1996: "*Activity Theory as a Potential Framework for Human-Computer Interaction Research*", (Ed, Nardi, B. A.), in *Context and Consciousness --- Activity Theory and Human-Computer Interaction*, MIT Press, Cambridge, Massachusetts, pp. 17-44.

Lübcke, Poul (ed.) 1996: "Politikens filosofi leksikon", Copenhagen, Politikens Forlag A/S.

Mathiassen, Mette. 2000: "Gyldighedsproblematikken i kvalitativ forskning - diskuteret fra et etnografisk perspektiv (Arbejdsrapport nr. 8)", Aarhus, Afdeling for Etnografi og Socialantropologi, Aarhus Universitet.

Nardi, B. 1996: *Studying context: a comparison of activity theory, situated action models, and distributed cognition*. In B. Nardi (Ed.): *Context and consciousness: activity theory and human-computer interaction*. Cambridge: MIT Press.

Pierce, Charles Sanders. 1994: "Semiotik og pragmatisme", København, Gyldendal.

Putnam, Hillary. 1981: *Reason, Truth and History*, Cambridge University Press, December 1981.

Schoonderwoerd, R and O. Holland, J. Bruten, and L. Rothkrantz. 1996: "*Ant-based load balancing in telecommunications networks*," *Adaptive Behaviour*, vol.5, No.2.

Schmidt, Kjeld & Carla Simone. 1996: 'Coordination mechanisms: Towards a conceptual foundation of CSCW systems design', *Computer Supported Cooperative Work: The Journal of Collaborative Computing*, vol. 5, no. 2-3, 1996, pp. 155-200

Schmidt, Kjeld, and Ina Wagner 2002a: 'Coordinative artifacts in architectural practice', *COOP 2002: Fifth International Conference on the Design Of Cooperative Systems, Sophia Antipolis, Saint Raphaël, France, 4-7 June 2002*, IOS Press, Amsterdam etc.

Schmidt, Kjeld, and Ina Wagner 2002b: 'Ordering systems in architectural design and planning: a discussion of classification systems and practices', Invited paper, *Conference on Distributed Collective Practices, San Diego, 6-8 February 2002*.

Schmidt, Kjeld and Liam J. Bannon. 1992: "Taking CSCW seriously: supporting articulation work", *Computer Supported Cooperative Work(CSCW): An International Journal*, vol 1, no. 1-2, pp. 7-40.

Schmidt, Kjeld. 2000: 'Distributed collective practices: A CSCW perspective', Invited talk, *Conference on Distributed Collective Practices, Paris, 19-22 September 2000*

Schmidt, Kjeld. 1994: *Modes and Mechanisms of Interaction in Cooperative Work*, Risø National Laboratory, P.O. Box 49, DK-4000 Roskilde, Denmark. [Risø-R-666(EN)].

Schmidt, Kjeld. 2002: 'Remarks on the complexity of cooperative work,' in Hakim Benchekroun and Pascal Salembier (eds.): *Cooperation and Complexity, RSTIA*, Hermes, Paris.

Schutz, Alfred. 1964: "The stranger: An essay in social psychology" (*American Journal of Sociology* 1944); in A. Schutz: *Collected Papers*, vol. 2, Martinus Nijhoff, The Hague, pp. 91-105.

Schutz, Alfred. 1962: "Common-sense and scientific interpretations of human action" (*Philosophy and Phenomenological Research*, September 1953); in A. Schutz: *Collected Papers. Vol I. The Problem of Social Reality*, edited by Maurice Natanson, Martinus Nijhoff, The Hague, pp. 3-47.

- Sellen, Abigail, and Richard H. R. Harper. 2001: *The Myth of the Paperless Office*, MIT Press, Cambridge, Mass., 2001
- Selznick, Philip. 1948: *Foundations of the Theory of Organization*. American Sociological Review, vol. 13, pp. 25-35
- Sharrock, Wes W.; and Robert J. Anderson. 1986: *The Ethnomethodologists*, Ellis Horwood Publishers, Chichester.
- Shannon, Claude E. 1948: 'A mathematical theory of communication,' *The Bell System Technical Journal*, vol. 27, July, October 1948, pp. 379-423, 623- 656.
- Shannon, Claude E., and Warren Weaver. 1949: *The Mathematical Theory of Communication*, University of Illinois Press, Urbana.
- Simon, Herbert A. 1979: *Models of Thought*, Yale University Press, New Haven and London.
- Suchman, L. 1987: *Plans and Situated Actions: the Problem of Human-Machine Communication*. Cambridge University Press, New
- Suchman, L. 1993: *Technologies of accountability: Of lizards and airplanes*. In Graham Button, editor, *Technology in Working Order: Studies of Work, Interaction and Technology*. Routledge, London and New York, pp. 35-60.
- Suchman, L. and R. Trigg. 1991: *Understanding practice: Video as a Medium for Reflection and Design*. In J. Greenbaum, and M. Kyng, editors. *Design at Work: Cooperative Design of Computer Systems*. Lawrence Erlbaum Associates, Hillsdale, NJ., pp. 65-90.
- Suchman, Lucy A., and Eleanor Wynn. 1984: "Procedures and Problems in the Office," *Office: Technology and People*, vol. 2, pp. 133-154.

- Susi, Tarja & Tom Ziemke. 2001: Social Cognition, Artefacts, and Stigmergy: A Comparative Analysis of Theoretical Frameworks for the Understanding of Artefact-mediated Collaborative Activity. *Cognitive Systems Research*, 2(4), 273-290.
- Sutton, R. 1991: *Reinforcement learning architectures for animats*. From Animals to Animats, pages 288—296.
- Smith, A.P. 1978: “An investigation of the mechanisms underlying nest construction in the mud wasp *Paralastor* sp. (Hymenoptera: Eumenidae)”. *Animal Behaviour*, 26, 232-240.
- Taussig, Michael 1993: ”Mimesis and Alterity – A Particular History of The Senses”, Routledge, London and New York.
- Theraulaz, G., Bonabeau, E. 1999: *A brief history of stigmergy*. *Artificial Life* 5 (1999) 97 – 116.
- Vygotsky, L.S. 1979: "*The instrumental method in psychology*", in *The Concept of Activity in Soviet Psychology*, J.V. Wertsch (ed.), 134-143, M.E. Sharpe, Inc. : Armonk, New York, USA.
- Weiser, Mark. 1993: *Some computer science issues in ubiquitous computing*. *CACM*, 36(7):74--83. In Special Issue, Computer-Augmented Environments.
- Weiser, Mark. 1991: *The computer for the 21st century*. *Scientific American*, 265(3): 94—104.
- White, T and Bernard Pagurek. 1998: *Towards multi-swarm problem solving in networks*. In *Proceedings of Third International Conference on Multi-Agent Systems (ICMAS'98)*, pages 333-340.
- White, T.1997: "*Swarm intelligence and problem solving in telecommunications*", *Canadian Artificial Intelligence Magazine*, Spring.

Wittgenstein, L. 1953: *Philosophical Investigations*. Blackwells, Oxford.