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INVENTING NEW USES FOR TOOLS: A COGNITIVE FOUNDATION FOR STUDIES ON APPROPRIATION

Antti Salovaara
Helsinki Institute for Information Technology
Helsinki University of Technology and University of Helsinki
Finland

Abstract: *Appropriation refers to the processes that take place when new uses are invented for tools and when these uses develop into practices and start spreading within a user community. Most research in human–computer interaction and computer-supported cooperative work to date has studied this phenomenon from a social sciences approach, thus focusing on the practice side of the phenomenon. This paper addresses appropriation from the other direction, drawing from ecological psychology and focusing on cognitive processes in context. Appropriation from this perspective is understood as an interpretation process in which the user perceives in a tool a new opportunity for action, thus acquiring a new mental usage schema that complements the existing uses. This approach highlights the need to study how schemata are put into use and how they evolve through new interpretations. Ensuing research questions are presented together with three strategies of applying the new approach in system design.*

Keywords: *appropriation, schema, artifact, tool, ecological psychology.*

INTRODUCTION

Appropriation—the invention of new purposes of use—as a phenomenon in human–computer interaction is gaining increasing interest, especially in computer-supported cooperative work (CSCW) research (e.g., Balka & Wagner, 2006; Bansler & Havn, 2006; Brown & Perry, 2000; Dourish, 2003; Huysman et al., 2003; Pargman & Wærn 2003; Petersen, Madsen, & Kjær, 2002; Salovaara, 2007). The reason for this is that, from the late 1980s until today, it has become increasingly clear that a system's use should be conceived more as a *projection* of its features instead of a direct *outcome* of the design (see, e.g., DeSanctis & Poole, 1994; Orlikowski, 1992). Design does not determine how and for what purposes a system will be used in real settings, but rather is a component in a more complex, evolving process in which unforeseen contextual features, social factors, creativity, and opportunism, as well as new user interpretations, also play a part. The result of such a process is a multitude of different uses for the same system, each use having a different history behind it. Put in another way, users often adapt their tools by transforming their use and even their configuration, thus making them suitable for ongoing practices in different environments.

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An often-used definition for appropriation comes from Dourish, who has captured the above-mentioned viewpoints in the following description:

> Appropriation is the way in which technologies are adopted, adapted and incorporated into working practice. This might involve customisation in the traditional sense (that is, the explicit reconfiguration of the technology in order to suit local needs), but it might also simply involve making use of the technology for purposes beyond those for which it was originally designed, or to serve new ends. (Dourish, 2003, p. 467)

It is clear that understanding appropriation is important for CSCW, human–technology research, and system design. By describing appropriation processes in different settings, it is possible to gain a better understanding of the nature of evolving patterns of use, the factors that support or suppress user innovation in everyday settings, the processes of user innovation, and the workarounds and strategies developed by users to overcome unanticipated problems. These findings can be turned into design implications, and they also sensitize designers to conceptualize their work in a new way. Through such awareness, design methodology can be improved to take into account better the variety and richness that can be found in many use practices.

Appropriation of technology has been mainly researched within CSCW by carrying out longitudinal follow-up case studies and applying theoretical frameworks to account for the observed activities. Examples of such applications of theories from other fields are the adaptive structuration theory (DeSanctis & Poole, 1994; Orlikowski, 1992, 1996; Pipek & Wulf, 2006; Tyre & Orlikowski, 1994; adapted from the structuration theory by Giddens, 1984), the sensemaking perspective (Bansler & Havn, 2006, originally presented by Weick, 1995), cultural-historical activity theory (Pargman & Wærn, 2003; Petersen et al., 2002), and ethnomethodology (Brown & Perry, 2000; Salovaara, 2007). The focus has been on deepening the understanding of human activity and supporting the design of more appropriable technologies. Appropriation research has also benefited from research on tailoring—how users adapt and modify systems to fit their work better (e.g., Pipek, 2005; Trigg & Bødker, 1994). Systems purposely built to support tailoring provide one way to achieve appropriable technologies. Allowing users to modify and adapt the systems gives them more freedom to find new uses for a system.

Technology appropriation is a widely used concept and has been given definitions in fields other than CSCW. Eglash (2004) has used it in social studies of technology to examine the politics of use and questions on the power to decide what a technology is used for. This has led him to study cases in which high-power designers (such as the architects of a building) and low-power user-consumers (such as graffiti artists) interpret the technology (in this case, a building) in different ways, rendering visible the dynamics of the proper use of technology. Eglash has conceptualized these dynamics as three appropriation categories that span a continuum from semantic reinterpretation to structural reinvention, leaving adaptation (as a change of use) in the middle. The presentation in this paper relates primarily to the middlemost category, but because the aim here is not to understand power relations, Eglash's categorization is not directly applicable to issues relevant to this paper.

Another sociological approach, the research on the consumption and domestication of consumer products (Silverstone, Hirsch, & Morley, 1992; Williams, Stewart, & Slack, 2005), also makes use of the term appropriation, using it to identify the steps of progressive

ownership in processes in which commodity products such as TV sets are bought from stores and gradually converted by their owners into objects that bear personal significance. The analysis of different uses is carried out under the concept of incorporation. Despite having a different name, it carries the same meaning as what is called appropriation in this paper. The purpose of analysis, however, deviates from that of CSCW and is more focused on consumption patterns than design.

A common topic raised across all these efforts has been an emphasis on how important it is to focus on the context-specificity of activities and practices: The setting for action is every time slightly different than before and that this affects the way in which different resources in the environment—digital and physical tools, other people, and so on.—are perceived, interpreted, and acted upon. This leads us to ask how users actually might interpret the possible uses of an artifact. Understanding interpretation has therefore a central role in understanding appropriation and artifact use in general.

Interpretations of artifacts are naturally affected heavily by the user's ongoing activities and goals, but also by experiences from previous situations of use and socially learned pieces of knowledge from other users. Often there are multiple interpretations of the same artifact, each having a different relevance from one situation to another. If we assume that all the situations bear some meaning for the user, we end up with the conclusion that there cannot be a single correct interpretation of an artifact.

In some cases, however, there is a demand for communicating only a single possible interpretation. It may be feared that a new use directly or indirectly has negative effects on users, other people, or society in general. This aspect is especially important in occupational health and safety-critical systems (e.g., Kjellen, 2000). However, in spite of this, the purpose of this paper is not to find ways to hinder people from inventing uses that someone could consider deviant or harmful. The aim is to remain neutral on such value attributions and instead focus purely on understanding how users come up with *any* new uses. By emphasizing the appropriating users' viewpoint, the focus is admittedly more on the "sunny" side of appropriation than on misuses and misappropriations. However, by adopting the user's viewpoint, unwanted appropriations can also be better understood and, if wished, the subsequent systems engineering and design efforts can then attempt to hinder such misappropriations from taking place. Work towards this direction is currently being carried out in computer security (Dhillon, 1999) and organizational e-mail misuse prevention (Attaran, 2000; Duane & Finnegan, 2004).

Whenever preventing users from appropriating is not an issue, the task for an appropriation-friendly designer is thus transformed. Instead of communicating only a single possible use as clearly as possible, the designer concentrates on making the device usable and useful for many different situations and users.

Approaching appropriation from the point of view of interpretation connects us with two lines of research that are especially relevant to the topic at hand. They represent two quite different fields of research: critical approaches drawing from the humanities and arts on one hand, and cognitive science on the other. Within the former field, it has been seen as important to engage the user in reflecting on the meanings of artifacts. For instance, Gaver, Beaver, and Benford (2003) advocate design that deliberately incorporates ambiguity in the presentation of information, the artifact's purpose of use, and its relationship with the surrounding social context. Such a design strategy provokes and engages users to question

easy and seemingly obvious interpretations in favor of personally more meaningful ones. They claim that using such systems can provide users with experiences of delight and intrigue. Similarly, by presenting a series of design case studies, Höök (2006) suggests ways to open the interpretation space of digital systems. For instance, a communication tool may provide a space for expressing different moods with colored backgrounds, whose meanings the users are free to negotiate on their own.

Sengers and Gaver (2006) take this perspective to a conclusion particularly relevant to the purposes of this paper. They present an idea of multiple interpretations, stating that the designer's idea of a tool's usage is not always the correct one, and therefore the correct design strategy would be to help users in creating their own interpretations of how an artifact can be used. Furthermore, designers should remember that the users' interpretations can even be in conflict with each other. The designer should let the user exercise freedom to choose what is best.

Whereas the approach arising from the arts has received attention in the human–computer interaction (HCI) research community, the cognitive approach has not been taken up to an equal extent. The purpose of this paper is to establish grounds for this line of research. Psychological studies of interpretation processes and their relations to actual usage are valuable in providing more systematically gained insight into how different interpretations are constructed in different settings. They can also complement the research on appropriation that has been carried out in CSCW and sociology by studying the ways in which an individual's interpretations contribute to the negotiations about suitable usages in collaborative settings.

APPROPRIATION FROM THE PERSPECTIVE OF COGNITIVE SCIENCE

Appropriation has the particular character of being hardly predictable, even to the extent that it is more likely to occur in anomalistic situations (Tyre & Orlikowski, 1994). It is also difficult to predict what elements in the context happen to contribute to the appropriation process. Appropriation processes therefore have a particular real-life flavor that is difficult to replicate in a laboratory. Cognitively oriented research on appropriation must meet this hindrance and be prepared to study a phenomenon despite this challenge. The requirement is, of course, not particular to cognitive science, as it holds for other theoretical approaches to appropriation as well. The difference to the approaches listed above comes from the emphasis on models and predictions in cognitive studies. Theory-building can be started with descriptive studies, but the final aim is to end up with something that can be subjected to empirical critique more directly.

Ericsson and Hastie (1994) have addressed ways to proceed towards ecological validity in research on thinking and problem solving. Their discussion is also suitable for the purposes of this paper. Ericsson and Hastie point out that psychologists have had particular problems in finding out how to take into account test subjects' previous experiences in analyzing experiment results. If a person is experienced in the tasks that she has to carry out, then her ways of solving the tasks are incomparable to the results of other participants. This problem has led to a research tradition that has advocated artificial problems or precise problem domains (such as chess) in which the test subjects are on the same level in terms of experience, either as experts or complete novices. This approach has sometimes led to studies

whose ecological validity other researchers have questioned (e.g., Lave, 1988). Ericsson and Hastie (1994) propose two strategies to improve the situation. One is to identify the relevant cognitive processes on such a fundamental level that they are always present in the cognitive tasks of interest, and therefore also in the artificial problems. If such processes can be found, they can be studied in controlled settings with better precision than in the real world. The other strategy is to go into the field and attempt to identify phenomena that could be replicated in a laboratory without losing the necessary characteristics of the phenomenon.

When studying appropriation, it likewise must be remembered that there are users with different skill levels and experiences. The approach presented below will tackle this by using the Ericsson and Hastie strategy as a guideline. In relation to the approaches mentioned above, the purpose is to provide a complementary perspective that has the potential to produce understanding that previously has not been excavated.

Appropriation as Development of Usage Schemata

This paper uses the theories in ecological psychology as its scientific background. Ecological psychology originated in the 1970s, when many psychologists found themselves dissatisfied with the ecological validity of the cognitive psychology of the time. Naturally, the quest for ecological validity was not invented then but dates further back in history to works by James, Brunswik, and the Gestalt psychologists such as Koffka, Köhler and Wertheimer (Heft, 2001). Later, ecological psychology was influential in the movement towards studies on embodied cognition, which seeks to overcome the problematic demarcation between mind and body in psychological research.

The interest in the processes of interpretation in this paper is the connecting link to ecological psychology. For the purposes of this paper, interpretation refers to the user's sense-making of an artifact's purpose of use. One way to approach the nature of an interpretation process is to think how a user perceives the resources for action that are necessary in the achievement of a goal. A resource can be close to an affordance (Gibson, 1979), such as a physical property that affords certain manipulations, but can also be something more elaborate, such as a new sequence of actions in a program to work on information.

Many activities are dependent on the skillful use of available resources, and it is important to study how they are perceived in the first place. The perception of resources develops through learning, that is, through experiences gathered by being in interaction with an environment and using different artifacts. Because skillful perception is dependent upon learning, the existence of resources is not independent of the perceiver. Resources are "there," available for action, only if the person has, for instance, seen them previously in effect, heard about them, tried similar resources before, or reflected about a need for such a resource in the past. Alternatively, learning can take place in a moment of interaction in which a user faces an immediate need to achieve something and starts to search for something that would serve the need. Resources are therefore personal, and each person may perceive the resources of an artifact in a different way.

If appropriation is interpreted as a process of perceiving resources facilitated through previous and immediate experiences, one way to conceptualize this is to see appropriation as a cycle of perception and action, in which both parts may change the other. Neisser (1976) has presented this idea as a perceptual cycle in which the concept of a schema directs the perception and orients the actions in the world:

> A schema is that portion of the entire perceptual cycle which is internal to the perceiver, modifiable by experience, and somehow specific to what is being perceived. The schema accepts information as it becomes available at sensory surfaces and is changed by that information; it directs movements and exploratory activities that make more information available, by which it is further modified. (p. 54)

The perception–action cycle can also be visualized with a help of a schema concept, as shown in Figure 1. The figure shows Neisser's original perceptual cycle on the left and one adapted for describing appropriation on the right.

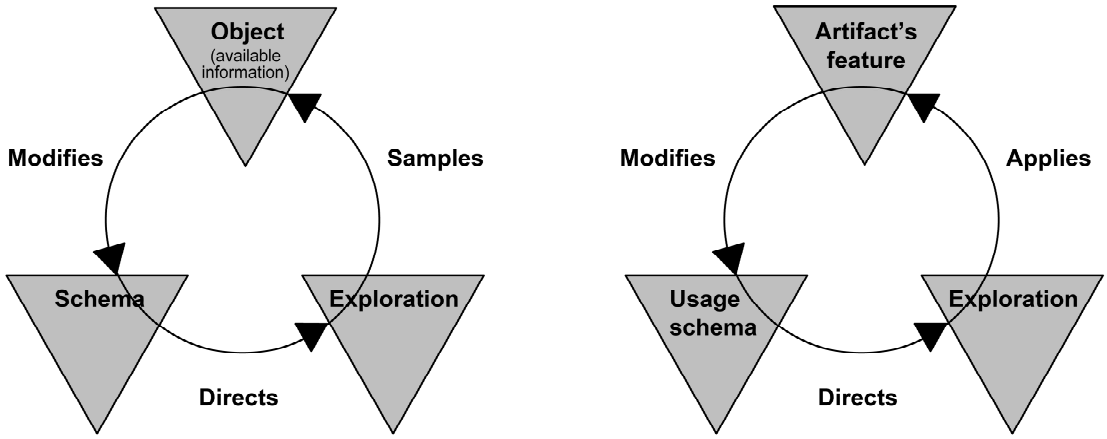

Figure 1. Neisser's perceptual cycle (1976, p. 21) and its adaptation for describing appropriation.

Comparison to Other Models

The model for appropriation presented in Figure 1 is different from certain other cyclical models used in HCI and CSCW. The task–artifact cycle (Carroll, Kellogg, & Rosson, 1991) presents a cycle of alternating stages of design and use that serves as an evolutionary model of the nature of technology development. When a user is carrying out a task with an artifact, new requirements for the artifact emerge, and when a new artifact is designed as a response to those requirements, it opens up possibilities for new tasks. Many of the typical user-centered design tasks, such as the creation of a design rationale and scenario-based design activities, can be mapped into the model (pp. 80–82). The task–artifact cycle is therefore a model about iterative product development, but does not address changes in use in cognitive terms.

The adaptation of Giddens' (1984) structuration theory—called adaptive structuration theory (Orlikowski, 1992; DeSanctis & Poole, 1994)—also contains a cyclical element. The original theory by Giddens introduces the concept "duality of structure," which is needed for building a bridge between macro-level theories on how social structure shapes action and micro-level theories on the continuous recreation of such structures (Giddens, 1984, pp. 25–28). Using this work as a starting point, developers of adaptive structuration theory have suggested that social structures are represented in artifacts' properties through the ways in

which they afford and constrain action and cooperation. Social practices develop to make use of these structures and in this way shape the social organization of the workplace (DeSanctis & Poole 1994; Orlikowski, 1992; see also Pipek & Wulf, 2006).

Finally, the action cycle by Norman (1988) models interaction with computers as a cycle, more specifically as seven stages. These stages are divided into goal formation and two "aspects" with three stages each. The aspect of execution contains stages for the formulation of intentions to act, the planning of a sequence of actions, and the execution of actions, while the aspect of evaluation consists of observation of the result and interpreting it and evaluating it to create new goals (p. 47). The model is close to the model presented here, but it is best suited for cases that resemble problem solving and in which learning during use is not a central element.

Of the models presented, none is targeted at describing appropriation through an individual's point of view, with an emphasis on cognitive processes. The closest of all three is the seven-stage action cycle, but it does not explicitly address the possibility of learning new cognitive representations through interaction.

Usage Schemata

While Neisser's (1976) model has not been applied in HCI as actively as the three others presented above, analyzing appropriation from its point of view has certain virtues. It provides a starting point for cognitive theory building that helps to direct research into novel aspects of appropriation, while at the same time also builds connections to the large body of research of higher cognitive processes (which are briefly discussed later in this paper). It also strives for ecological validity—an important requisite for HCI—that is concerned with everyday activities.

The usefulness of the new model can be exemplified by using it to analyze episodes that describe actual appropriations. Table 1 provides three such examples. They may seem quite eclectic and sketchy, but this is due to a lack of studies that would have documented appropriations systematically from the point of view presented in this paper. They can nonetheless highlight ways of using some of the model's features.

Looking at Table 1, certain qualitative differences in the nature of appropriations can be noted. The first two examples are workarounds in which an artifact is used as a replacement because a better solution is not available. In contrast, the third episode is an example in which a new technique for making music is born and nothing is replaced. Instead, a completely new kind of activity is invented. In addition, the first two appropriations result from problem solving, whereas the third takes place serendipitously, without intention.

However, more important than building classifications is to analyze the episodes in terms of the model's primary theoretical concepts: perception, schemata, exploration, and action. In the first two episodes, the perception of a new possible use is the result of making a match between the task requirements and the resources at hand in the environment. In both cases, the person is forced to engage in matchmaking because she does not have a usage schema for any of the surrounding artifacts that would directly solve the problem. Therefore the environment is explored in order to find something that would fit the requirements. The exploration is successful: The person is able to apply a feature or features of an artifact to the task at hand. This results in a new usage schema for the artifact.

Table 1. Three Episodes of Appropriation.

Episode 1: Using a panty liner to cope with a blister "I was in the city centre with a friend of mine, and we had been walking quite a lot. I was getting a bad blister on my heel because of my new shoes, and wondered what I could do to improve the situation. I had a plaster in my handbag, but it wouldn't have been thick and big enough. I needed something that would fit better in the shoe, something that would not come loose when walking, and I needed it at that moment. After thinking about this for just a short while I realized that a panty liner would be perfect; it would meet all the requirements listed. It also solved the problem." (Source: Personal communication with a female friend of the author)
Episode 2: Using an ethnographer's camera to replace a faulty video conferencing system An excerpt of field notes from an observation of setting up a video conference: <Unfortunately, the phone line is very poor and breaks up often. This brings on an interesting piece of behaviour – TN [student mentor] notices me [observer] and attempts to bring another, more compatible form of media into use> TN: I'm wondering if we have a tape recorder, or video and can send you … a copy of <looks at the ethnographer and the video recording equipment> … okay, you have a video <points at the ethnographer>, okay, yeah, <looks back at the team> we have a video of this, so maybe we can send you a video discussion later, so that you can watch it. (Source: Perry, Fruchter & Rosenberg,1999, p. 147)
Episode 3: The invention of the scratch sound (also called "needle drop" below) in hip hop music Interviewer: "So Grandmaster Flash says that you invented the needle drop; tell me how you discovered that?" Grand Theodore Wizard: "I was probably about 11 years old when I pretty much came up with the needle drop and 12 and half years old with scratch, the summer of 1975, which marks 30 years of the scratch this year. I was just basically in my room just practising and playing music a little bit too loud. My mother is the kind of person that doesn't argue or fight or fuss [;] she just start swinging[,] you know like Mike Tyson. I'm in the house trying to make the tape and back in those days you didn't have no tape decks or anything like that[;] its just take a big boom box and put it in front of the speaker and that's how we made our tapes. I was making a tape and she came in the room and banged on the door and I was like 'oh man…'[;] she looked at me and the look was like either turn your music down or turn the music off, so I had one record playing on my right hand side and I was holding the record on my left hand side and back then we didn't have no cross faders like the up and down fade, so I had all the up and down faders all the way up and whiles she was screaming at me in the doorway[,] I was rubbing the record back and forth and forth and back, so when she left the room I realised what I was doing and practiced it and perfected it and it became a scratch and the rest is history." (Source: interview of DJ Grand Wizard Theodore, ukhh.com Original UK HipHop 2005; see also Goldberg, 2004)

In the third episode a new usage schema (about a new way of manipulating the turntable) is also created, but the role of goal-directed exploration is much weaker. The exploration is actually directed at turning down the music, which is achieved by "rubbing the record back and forth." The perception of a new use comes only after that, as a result of exploration and interaction that has originally served a different purpose. After this realization, the perception results in a schema that will serve to direct future interactions and explorations with the device.

Some comments about the nature of the main theoretical concepts can be made based on these examples. First, as was already said above, the perception of a new use is strongly dependent on interpretation. Perception without interpretation would not be able to address the evaluation of the usefulness of the new usage, but would treat any random use as an appropriation. In addition, most new uses are also not directly perceivable by the senses but need more conceptual processing. For instance, the first two examples showed examples of planning and mental simulation before any actions were actually commenced.

Second, the artifact's features in the model can denote the whole artifact or just a part of it, as emphasized also by Sengers and Gaver (2006). In all three episodes in Table 1, the new schema was created for the whole artifact, but, for instance, many appropriations related to basic office programs address only certain features in a program. This shows clearly in cases when a piece of data is copy-pasted across programs in order to make all the necessary changes to it, each one with a different program:

> For example, a report may need some data in a particular form and style. The data might be collected by a number of searches in an internal database, and on the web and pasted into Excel so that all the results could be composed. A graph might be drawn in Excel, but require some tweaking that was done in Paint before pasting it into a Word document and passing it on to a colleague for help. (Twidale & Jones, 2005, p. 81)

Third, schemata resulting from appropriations are long-term mental representations, and therefore learning a new schema has a permanent effect on structuring a user's actions in the future. The schema can also direct later explorations of features in the environment and in this way contribute to new appropriations. As a result of new appropriations, multiple usage schemata will be created for the same artifact and its features over time. A new schema thus does not replace or override the existing usage schemata, but it will coexist alongside earlier ones.

The following sections will start to chart the connections of this approach with the existing domains of research in psychology and cognitive science. As a result, more specific research questions can be formulated and methods introduced to answer them.

Representations and Embodied Cognition

Schemata belong to a larger class of mental concepts called representations. In the literature to date on ecological psychology and embodied cognition, the nature of representations has been discussed actively (Brooks, 1991; Clancey, 1997; Clark, 1997; Lave, 1988; Reed, 1996; Varela, Thompson & Rosch, 1993; Winograd & Flores, 1986). Some researchers have stated that committing to the existence of representations is antithetical to the idea of embodied cognition (e.g., Brooks, 1991; Varela et al., 1993). To exaggerate the argument, a conflict arises if representations are interpreted as symbolic units, each containing pieces of information that a human mind would manipulate using abstract rule-like operations. This interpretation would lead to advocating the disembodied approach on cognition that assumes that external stimuli are encoded into a "language of thought" before they are cognitively processed.

In opposition to the disembodied view, this paper follows the conceptualization of Clark (1997). Without taking an explicit stance on how representations are manifested physically in the brain, Clark requires that representations (and thus also schemata) must be seen as action oriented (pp. 47–51 and 147–153) in that they "simultaneously describe aspects of the world

and prescribe possible actions, and are poised between pure control structures and passive representations of external reality" (p. 49). Such representations have a situation-specific nature. Thus, they help to structure human action in the world, but they need not be abstract symbolic models of that world.

Relationship to Other Higher Level Mental Representations

Other often-discussed higher level mental representations, in addition to schemata, include mental models and scripts. Mental models denote a whole category of representations that describe people's understanding of the world and its laws and dynamics (e.g., laws of gravity; see chapters in Gentner & Stevens, 1983), the understanding of grammar (Johnson-Laird, 1983), laws of human reasoning (Johnson-Laird, 1983), and the interpretation of narratives (Bower & Morrow, 1990). Closest to the interests of this paper is the research on world models when applied to the understanding of the inner workings of electronic devices. In the words of Carroll and Olson (1988), a mental model "is a rich and elaborate structure, reflecting the user's understanding of what the system contains, how it works, and why it works that way" (p. 51). When studying mental models in this way (see also Bibby & Payne, 1993, 1996; Kieras & Bovair, 1984; Norman, 1988; Payne, 2003), the focus differs from the interests of appropriation in that the emergence of an artifact's purpose of use is not the primary concern. Instead, researchers have investigated the processes of how users learn to operate a device in a uniform manner. Another research question has been how users' reasoning of how a device works differs from the device's actual operation. In these experiments, the interpretations of the device's purposes of use have not been allowed to vary because that would have compromised the comparability between test users.

The research on scripts, on the other hand, is mostly associated with the work by Schank and Abelson (Schank, 1982; Schank & Abelson, 1977) and subsequent work both in artificial intelligence and cognitive science. Schank and Abelson explain a script as a structure that "describes appropriate sequences of events in a particular context" (1977, p. 41), which often have default values for each item in the structure, unless the items have been instantiated with the contextually determined values. Scripts, while describing how to do certain things, have not been artifact centered. That research has not therefore produced findings on appropriation.

IMPLICATIONS FOR RESEARCH

Psychology is a field with an emphasis on explication and theory testing with systematic methods. To embark on this process, this section addresses research strategies and the ensuing research questions.

Research Strategies

Related to the commitment to the embodied nature of representations is a need to define the ecological approach to research. The level of the "ecologicality" of analysis is related to the importance given to the situatedness of representations. A radical approach would be to treat the representation in each situation as different, leading to a denial of any generalizability of

usage schemata. Fortunately, such a position need not be maintained because users are often found to show opportunistic uses of tools based on previously learned usages. Some transfer and learning across situations must therefore take place. With permission to make comparisons between cases to find larger patterns, two strategies can be described that preserve a suitable ecological validity.

The first is the already mentioned strategy of identifying phenomena in real life and converting them to studies in more controlled settings (Ericsson & Hastie, 1994). In research on appropriation, this strategy is mostly suitable for studying opportunistic and emergent behavior when the task is given to a user by the researcher. For instance, a particular study by Galantucci (2005) can be used as an inspiration. He conducted an experiment on the emergence of language in human–human communication. Subjects were asked to carry out a collaborative task through a system that forced them to construct a new language that could only be based on drawings on a sketchpad. This setup allowed researchers to analyze the variation and commonalities of different expression–object mappings that the subjects tended to develop during the course of interaction. Similar kinds of research designs could be devised, for instance, to study new forms of communication with digital media. The tasks administered must, of course, bear real-life relevance to test subjects.

Studies that follow the strategy devised by Ericsson and Hastie can uncover the ways in which users find new means for reaching a goal, but are poor in addressing how new goals of activity will emerge. Related to the examples given in Table 1, this strategy would work better for the two first episodes (the blister and recording device examples) than the third one (the music instrument example).

The other strategy—which has a better chance at succeeding in studying the emergence of new goals—is to start by identifying suitable action settings. Those with a clear asymmetric balance between the amount of an artifact's functionalities and the approximate number of appropriations are of particular interest. For example, a camera is an artifact that has a rather straightforward functionality (taking pictures), but it can be used in many settings. This creates an asymmetric 1–to–N mapping. A longitudinal study can produce data on how a user perceives new opportunities of action for the picture-taking functionality in different settings and how the interpretations of the camera therefore undergo changes and become more varied. Adobe Photoshop and certain script programming tools can be used as examples of the opposite N–to–1 mapping. In these cases, the tool offers many alternative avenues for reaching the same goal. Also in this case it is possible to start mapping the perceived functionalities of the artifact to the user's goals.

Studying N–to–N cases is not out of the question but, because the interrelationships can become complex in these cases (and even more so if they involve social processes), studying such appropriations is very challenging without a clearly defined theoretical framework. Currently no such framework exists since the existing ones (see the list of CSCW-based frameworks above) can only provide descriptive accounts of appropriation. However, studies in complex settings are useful in picking out interesting appropriation-related phenomena. For instance, Aoki and Woodruff (2005) have identified different face-saving strategies (e.g., white lies) that instant messaging users may develop to explain why their responses to others' messages are sometimes delayed. In many of these cases, the users appropriate the potential errors in the system as excuses for their nonresponsiveness. As will be mentioned more fully

below, phenomena such as face-saving can later be turned into more precise studies on cognitive appropriation processes.

Questions for Future Research

The primary question that motivates all cognitively oriented appropriation research is to find out what kind of cognitive process is taking place when usage schemata originate and change. This question is very similar to the question that has been posed for all the schema theories in general, and also has been seen as the primary weakness of the idea of schemata in general (for criticisms, see Dahlin, 2001; Eysenck & Keane, 2000, p. 256;). The problem is that, because schemata are observable only indirectly, any changes in action can be explained post hoc by stating that a schema change took place. Such claims prove very little theoretically. One reason for this is that Neisser's (1976) perceptual cycle model provides an account of the stages of the learning process but does not describe what happens at each stage. Upon facing this problem during the 1990s, research in psychology turned away from general schema concepts and chose to tackle the related issues on a more particular level, for example through concepts such as event coding (Hommel, Müsseler, Aschersleben & Prinz, 2001), perceptual symbol systems (Barsalou, 1999) and less representationally laden topics such as motor skills (Willingham, 1998) and connectionist models (Botvinick & Plaut, 2004). The studies of appropriation in HCI cannot yet make full use of these steps of progress, and there is a gap to be filled with new research findings. Cognitively oriented appropriation research also has the potential to inform general schema research, as well as to make progress in its own field. The following questions may provide useful starting points for fertile research.

First, one research track is to study the temporal characteristics in the changing interpretations of a tool. With enough of a temporal span and close data collection of actual use, supported with verbal reports or other probing methods, models of perception–interpretation–action relationships can be built (for an example of the method but a different theoretical framework, see Salovaara, 2007). A more structured approach is to use the artifact itself as a research tool. For instance, changes in its design (e.g., a different visualization of its functionalities) may contribute to different interpretation processes. Another approach is to find people who are in the process of acquiring a new technology, and carry out a follow-up study (e.g., Petersen et al., 2002). Longitudinal studies can help to identify both breakthrough moments (if such exist) and hindrances in appropriation. Whenever a more structured approach is possible, it provides the possibility to tie the cognitive processes more closely to the design features of the artifact itself.

Second, a class of questions arises from the comparisons of different schemata. What are the characteristics of such schemata that represent clever appropriations? The underlying construction processes of rich schemata can be investigated by studying those people who appropriate actively and whose usage schemata therefore are more varied than others'. Also, retrospective analyses of such users' usage histories may reveal important contributing factors.

Third, related to the previous point, comparisons can also be carried out between novice and expert users of technology to understand the differences between their usage schemata. Such findings have a good potential for surprise: On one hand, experts have encountered a larger variety of situations, and therefore the scope of applicability (and the number of appropriations) for the artifact should be larger. On the other hand, experts might have been

habituated to existing use patterns and cannot observe new opportunities (see, e.g., Wiley, 1998). It will be important to find out ways to avoid getting fixated on existing use patterns.

Fourth, the situation specificity of usage schemata should be studied to assess the possibility for transfer of learned usages to new task domains and contexts. The design of appropriable artifacts should strive to facilitate all kinds of transfer and especially train users to pay attention to new opportunities of use. Research would tell us how feasible such a goal is.

Finally, in the spirit of the strategy proposed by Ericsson and Hastie (1994), the existing appropriation research and mundane everyday situations also can suggest phenomena that could be studied in more controlled settings: the processes of reflection-in-action when carrying out interactive problem-solving tasks (Schön, 1983), the already mentioned uses of interactional ambiguity in digital communication systems (Aoki & Woodruff, 2005), and learning processes to maintain parallel communication through using multiple channels (e.g., voice chat and text chat) in multiplayer computer games (Chen, 2007).

IMPLICATIONS FOR SYSTEM DESIGN

While detailed studies on interpretation processes would certainly help in proposing design principles for designing more appropriable systems, the theoretical framework depicted above can already highlight some central aspects. A set of design implications is presented below. Although similar suggestions have been published in previous literature as well (for a condensed list of such guidelines, see Dix, 2007), they have not had a connection to the concepts in the cognitive research approach.

Visualization of an Artifact's Effectors

Being able to perceive what an artifact is able to do within its environment in each situation is a requisite without which a user cannot develop a rich set of different usage schemata. If the user can see how the artifact connects to its environment and how it can make changes to it (i.e., what are its "effectors"), she is better able to find new uses for it. In a simple case, the perception of effectors is based on artifact's physical affordances. However, digital artifacts are often more complex than that, and therefore more complex reasoning and interpretation is often needed. To aid in such processes, the artifact's connections to the digital information space need to be made easily perceivable or noticeable through interaction.

To achieve maximal appropriability, the user should be supported in finding mappings from the functionalities of the artifact to a large number of goals. To do this, the designer can either think of different uses of the artifact and then visualize them for the user, or abandon the strategy of predicting the user's tasks and just visualize the effectors in a maximally transparent way, so as to help the user perceive what lies behind the artifact's most apparent uses. The challenge in applying this approach as a general rule, however, is to avoid providing too much detail and too many functions through the interface (Twidale & Jones, 2005).

The mobile awareness system ContextContacts (Oulasvirta, Raento, & Tiitta, 2005) and its commercialized version Jaiku[1] are good examples of how these principles can be used. It replaces the contact book in the user's mobile phone with another directory that, in addition to showing names and numbers, displays contextual information about each other person who

also uses the system. Based on the GSM cell ID, neighboring Bluetooth devices, a log of recent interactions with the phone, contents in the user's mobile calendar and so on, the system is able to deliver information about other users' locations, nearby friends, time lapses since last use, phones' ringing profiles, and the activities that other users might be engaged in at this and the next moment. All the information is collected unobtrusively without prompting the users. By visualizing this information in the contact book—the most often used application in the phone in addition to the text message editor—users are enabled to make inferences about each other in ways not previously possible. This provides possibilities for many opportunistic, serendipitous interactions (Oulasvirta, Petit, Raento, & Tiitta, 2007).

Making the Artifact Ubiquitously Available

Related to the previous item, appropriation is also supported by affording the tool for interaction in multiple situations. This maximizes the user's contact time with the artifact and the probability of mapping it to new goals. The reason why this is beneficial is thus similar to what was said above: providing more opportunities for use contributes to the construction of new usage schemata.

Two ways of doing this are obvious. One can facilitate availability by making the artifact physically easy to carry (e.g., implementing a program in a mobile phone). A second, indirect way is to make the system accessible from many devices (such as providing an interface to the program from a dedicated software program, a mobile phone, or a Web application). E-mail is an example of a system accessible from many terminals, and this has contributed to special uses. For instance, a user may send an e-mail with an attachment to her own address in order to enable access to the attached document in a different location from another terminal.

A third method is more indirect and is related to the fact that often tools are not used in isolation but together with other tools. This means that only a part of an artifact may be relevant to a user. For instance, a certain feature may be needed only to serve as a supplement to another artifact, as the example of copy-pasting in the Twidale and Jones (2005) paper cited above. To make artifacts useful in these cases as well, their design should support carrying out incomplete task sequences by allowing easy entries and exits to and from the application. Artifacts should not force users through the primary functionalities in a tunnel-like manner that does not allow any deviations. Likewise, by-products and side effects of use might also prove useful in some situations.

In standard desktop applications, implementing full support for copy-pasting is a good way to achieve the third solution. This solution has not been fully propagated to other computing systems, however. For instance, it would be useful in mobile phones, when data needs to be copied between calendar events, phonebook entries, and the text message editor. Although solutions to this exist (e.g., a dedicated pen button in high-end Nokia phones), it is not supported in all applications, and its use is both unobvious and requires effort (e.g., the use of both hands).

Propagating Good Usages

Finally, whenever someone invents a good use, it is beneficial to let others know about the new use as well. This can happen by learning through example. Many studies (Bansler & Havn,

2006; Kellogg & Erickson, 2005; Mackay, 1988; MacLean, Carter, Lövstrand, & Moran, 1990; Nardi, 1993; Trigg & Bødker, 1994) have pointed out that, especially in workplace settings, many good usages are invented and distributed through certain knowledgeable people— in the literature called mediators, gardeners, translators, or tinkerers—who have started to teach others the appropriations that they have come up with or heard about.

The presence of mediators is beneficial, but learning from others is not always completely dependent on them. In some cases, users can be encouraged to verbalize their usages or develop names for certain ways of use and thus make them referenceable in discussions. This serves the purpose of converting the usage schema into an externalized form. Macros in office software serve this purpose, but adopting them from others may require programming skills, and sharing them is not always easy (for an example of a system with shareable macros, see MacLean et al., 1990). It is also common that people develop special vocabularies within sports and music to describe movements and techniques. Episode 3 in Table 1, for instance, mentions needle drops and scratches as particular techniques unique to DJ'ing. The invention of such concepts enables the members of the community to communicate about each other's appropriations. This also serves the purpose of externalizing usage schemata.

An alternative approach is to make the usage more visible to other users. This can be as simple as making more visible the interaction with the tool. For example, a digital camera owner might see another user taking a picture of a map on an information display and may learn the use of a camera for note-taking from that example. This would not be learned if the map was downloaded to a phone by sending a text message to a special mobile service and getting the map back as a result. Alternatively, in some cases, documents and other products created with a tool may allow other users to see the building blocks or steps that were needed in creating them. HTML pages are an example of this: Upon finding a well-designed Web page, it is possible for anyone to see what code has been used to create it. In a similar manner, although this is less common, new ways to manipulate images can be learned by looking at how layers have been used in programs such as Adobe Photoshop and GIMP. However, preserving the layer structure when distributing images is rare among designers because the file sizes for layered images can be very large. It is therefore more common that the uses of layers are discussed in Web forums and with colleagues, without sharing the actual files. The idea can, however, prove useful in other design contexts.

CONCLUSION

Cognitive psychology has often been the target of criticism in current HCI and CSCW literature because of its assumed disregard of the importance of the context of activity. This critique (e.g., Bannon & Bødker, 1991; Kaptelinin, 1997; Kuutti, 1997) is often directed towards the by now two-decade-old model-based information processing theories that were developed to understand desktop-based interaction (e.g., GOMS; Card, Moran, & Newell, 1983). The contemporary context of interaction with computers and computing infrastructures is very different from the situation back then, and therefore the psychological approaches are also being adapted. This has already happened in mobile HCI research (e.g., Oulasvirta, Tamminen, Roto, & Kuorelahti, 2005). In a similar vein, this paper has sketched a research approach for

studies on appropriation, drawing from ecological psychology, presenting research questions, and describing ways to improve artifacts to suit into everyday tasks better.

By doing this, the paper has attempted to show that appropriation can and should be studied cognitively. This new perspective differs from previous research by aiming at developing research questions that can lead to systematic empirical work and ultimately to models, hypotheses, and theories that can supplement the existing appropriation research with new ideas.

ENDNOTE

1. See www.jaiku.com for more information.

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All correspondence should be addressed to
Antti Salovaara
Helsinki Institute for Information Technology (HIIT)
P.O.Box 9800
02015 TKK, Finland
antti.salovaara@hiit.fi

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