Ubiquitous Substitution

Christina Brodersen, Susanne Bødker and Clemens Nylandsted Klokmose

Department of Computer Science, University of Aarhus, Denmark
{sorsha, bodker, clemens}@daimi.au.dk

Abstract. Ubiquitous interaction places the user in the centre of dynamic configurations of technology, where work not necessarily is performed through a single personal computer, but supported by a multiplicity of technologies and physical devices. This paper presents an activity-theoretically based framework for analyzing *ubiquitous substitution*, i.e. a set of mediators that are or can be continuously substituted with the purpose of highlighting expected and indented uses, and the conflicts encountered when attempting substitution between them. The paper develops a four-leveled analysis of such mediators, and point towards a minimalist approach to design of ubiquitous interaction.

1 Introduction

The recent development of computing–whether it is called pervasive, ubiquitous, tangible, or ambient–changes the relationship between the human being and the computer from "one-to-one" to "many-to-many". This development challenges our understanding of human-computer interaction; where previously the focus of HCI has been on one technology-one application-one user, all packaged into one monolithic unit, ubiquitous interaction is about changing configurations of input and output devices, applications and users.

In classical HCI, there has until now been two ways of understanding and designing to suit users: Either to ignore user competence and design for novices only, as was often done in the first generation of HCI; or to do in-depth analyses of user needs as in the second (Bannon & Bødker, 1991). In both ways of thinking, however, the idea has been to design a new mediator as a *permanent* substitution of the old.

In first generation HCI, very minimal assumptions about the users were made explicitly. Yet, Buxton (1986) derives the underlying model of the human user from an analysis of existing mediators at the motor-operational level. Bannon (1986) notes how all mediators contain a theory of the user and the task domain, with reference to "idiot-proof" design philosophies that were implicit in some first generation HCI. With a few exceptions, such as key-stroke level analysis (Card et al, 1990), this quite reductionist approach did not provide any methods to help compare mediators and forms of interaction.

In the second generation, the focus has been on context and on understanding current and future use situations to understand the needs of the users. Learning has been important and hence, it was OK for users to spend time learning, and accordingly developing a new repertoire of actions and operations. Bardram & Bertelsen (1995) and Bødker & Graves Petersen (2001) took early steps towards focusing on learning from one mediator to another, yet the challenges for ubiquitous interaction design are a bit different: The *ubiquitous substitution* that we design for is not a permanent substitution of a full mediator with another (for example a typewriter with a word processor). It is a sort of design that focuses on how to substitute one mediator with another in a way that enriches the human repertoire of actions possibilities, hence, making possible continuous substitutions in terms of switching between mediators. Ubiquitous substitution is not a matter of breaking down and replacing one kind of mediation with another, but providing a larger "toolbox" and a better understanding of which mediator to apply when.

This paper focuses on such ubiquitous substitution. The theoretical account is based on activity theoretical HCI as it has been developed by Bødker (1991), Bertelsen (2001), Kaptelinin (1995a), with more recent inspiration from Gibson as developed by Bærentsen & Trettvik (2002), and from Bedny et al. (2000). We use the term *mediator* to cover a configuration of physical devices, logical interaction possibilities, functionality, etc., that serves a particular purpose to users (Kaptelinin, 1995b). We will return to these theoretical concepts in the following.

To illustrate our theoretical elaborations, we use examples from a recent empirical study (Bouvin et al., 2006), where geographical maps were used on three different technologies: A paper map in a telephone book, a web based digital map on a tablet-PC, and a digital map on a GPS enabled Nokia smart phone. The mediators are different but share some similarities: All three devices are relatively small and can be carried around, shared between users, and handed from one person to another while in use. In the study, we asked groups of two users to solve simple assignments looking at the map and out the window. Each group was given eight assignments that they had to solve, e.g., locate north, identify a local school and find the distance and direction to it. All assignments were created to relate to buildings and objects that were visible through a large window. The sessions were recorded with two videocameras covering different angles; still-shots were taken with high frequency, and all sessions were transcribed and analyzed in activity theoretical terms (Bertelsen & Bødker 2002).

The paper is structured as follows: First, we develop the theoretical framework with emphasis on functional organs. Through an analyis of the use of different map technologies, we demonstrate elements of the framework and discuss how the results can be used to understand substitution between mediators. We conclude by describing the challenges they pose for ubiquitous substitution, and the formation of functional organs in ubiquitous interaction.

2 Human Activity and Functional Organs

Human activity can be analyzed according to three layers: Activity, action, and operation (Bertelsen & Bødker, 2002). Activity is directed towards satisfying a need through a material or ideal object and the activity layer focuses on motivation and analytically addresses the question of *why* something takes place. Human activity is carried out through actions. These actions are governed by the conscious goals of the subject, and accordingly the analytical layer focuses of *what* takes place. Goals are different from the motive. They belong to the level where we immediately meet human activity in an analysis, because they are conscious. Goals reflect the objective results of action. Actions are realized through series of operations; each "triggered" by the conditions and structure of the action. They are performed without conscious thinking, but are oriented in the world by what Kaptelinin (1995a) calls an unconscious orienting basis. According to Bærentsen & Trettvik (2002), operations may be cultural-historically developed or naturally evolved, ecologically determined. Accordingly, they may realize internalized cultural-historical patterns of conduct or inborn species-specific patterns of behavior. Thus they result from appropriated use of tools, educated manners towards other human beings or movements in the physical world according to concrete physical conditions. Actions are dynamic structures where only the goal can be assumed to be conscious. Operations are never fixed, but adapted dynamically to the conditions of the environment. Actions are thought as a recursive structure, consisting of both conscious and non-conscious sub-actions and operations.

Bedny et al. (2000) introduce the concept of strategies described as plans for goal achievements that are responsive to external and internal conditions. We distinguish between strategies and routines; strategies have to be consciously developed when human beings are to perform an action. Strategies turn into routines when the predisposition to perform a certain action becomes partly automated, or into non-conscious–meaning we become familiar with while performing the action and similar actions. Figure 1 is adopted from Bertelsen & Bødker (2002), Bærentsen (1989) and Bærentsen & Trettvik (2002) and shows the relation between the three analytic layers.

Analytic layers	Mental representation	Realizes	Level of description	Analytical question
Activity	Motive (need)–not necessarily conscious, but may become conscious	Personality	The social and personal meaning of activity, its relation to motives and needs	Why?
Action	Goal–conscious	Activities (systems of actions organized to achieve goals)	Possible goals, critical goals, particularly relevant sub-goals Strategies	What?
Operation	Condition of actions (structure of activity)–normally not conscious, only limited possibilities of consciousness	Actions (chains of operations organized by goals and concrete conditions)	The concrete way of executing an action in accordance with the specific conditions surrounding the goal. Routines	How?

Fig. 1. Human activity and its analytic layers

Activity theory understands human beings as dialectically recreating their own environment (Bertelsen & Bødker 2002). Subjects are not merely choosing from possibilities in the environment, but actively creating the environment through activity; *"new tools shape new goals"*, as Kaptelinin (1995a) puts it. Whereas any specific human activity can be understood as activity, action or operation, none of these are fixed; an action can become an operation through internalization, and an operation becomes an action through conceptualization in breakdown situations (Bødker 1991).

The historical development of activity implies a development of artifacts and environments. Modes of acting within an activity system are historically crystallized into artifacts. In this sense, the historical development of activity can be read from the development of artifacts mediating the practice (Bærentsen 1989, Bannon and Bødker 1991). Activity is crystallized into artifacts in two ways. Firstly, they are externalizations of operations with earlier artifacts, and secondly, they are representations of modes of acting in the given activity. Kaptelinin (1995b) captures the functionally integrated, goal-oriented configurations of internalized operations and procedures (routines and strategies), and external mediation in the term *functional organ*. When a mediator is well integrated into the functional organ, it augments the human capacity, whereas if not, the mediator is outside the human user.

This means that when we study mediators, tools and devices, it is important to understand the extent to which they can be integrated into a functional organ. What efforts are needed to provide such integration? How may exploration of the intended use be supported, and how may some of the possible, yet less desirable uses be blocked (Bærentsen & Trettvik, 2002)?

Mediation and functional organs

Bødker (1991) proposes to analyze mediation through three aspects of the mediator: *The physical aspects* are the support for human operations towards the computer application as a physical object; *the handling aspects* support operations towards the computer application. The handling aspects are the conditions that allow the user to focus on the objects of the activity. *The subject/object* directed aspects constitute the conditions for operations directed towards objects or subjects dealt with in or through the artifact.

Bærentsen & Trettvik (2002) combine and extend the use of Gibson's (1979) affordances with activity theory. They talk about the *"network of technologies and praxis that are the basis of (..) affordances"*, and identify three types of affordances to match activity, action and operation in activity theory: Need-related, instrumental, and operational affordances. The need-related affordances relate to what motivates people, the instrumental to the socio-culturally shaped action possibilities in instruments and objects surrounding us. The operational affordances, Gibson's original type of affordances for movement in the four-dimensional physical world, describe action possibilities relating to our *"naturally evolved, ecologically determined patterns of behavior and conditions."* By distinguishing between the adaptive operations that are our low-level response to natural conditions, and conscious operations that are our repertoires of cultural-historical "training", we are able to identify the lowest level in the operation hierarchy, where we are confronted with the operational affordances. Affordance is a concept focusing on the relationship between the human being and the environment. In order to grasp how devices or artifacts are and become part of such relationships, we need concepts that help us focus on the device as well as on human action. Bødker's (1991) three kinds of aspects match these three types of affordances in a manner that makes it possible to understand how current mediators are integrates in the functional organ of the human users; which possible and desirable uses they afford and how, and which they do not. The relationship between affordances, aspects and activity can be seen in figure 2. This mapping requires a re-interpretation of Bødker's aspects and integration with the concept of functional organs. Physical aspects encompass adaptive operational affordances, and we will choose to use this term, since “physical” is slightly misleading. In Bødker’s three aspects, the need-related or activity-related aspect is missing, and since Bærentsen & Trettvik’s convincingly argue that it needs to be there, we include it. We prefer to use the term ‘instrumental’ to subject/object directed aspects, whereas we use handling rather than conscious operational, as it indicates to us a focus on how mediators become transparent in use, rather than on how they have once been conscious. The resulting four analytical layers of a functional organ can be seen in figure 3.

Affordance	**Aspects**	**Activity**
Need-related		Activity–why
Instrumental	Subject/object directed aspects	Action/strategy–what
Operational - Conscious - Adaptive	 Handling aspects Physical aspects	Operation/procedure–how

Fig. 2. Mapping between affordance levels, Bødker’s aspects and activity

Analytic layer	**Functional organ**	
	Mediator/external	**Routines/internal**
Need-related–why?	Need-related aspects	Motivational routines
Instrumental–what?	Instrumental aspects	Actions and strategies
Operational–how? Handling Adaptive operational	Operational aspects - Handling aspects - Adaptive aspects	Operation and routines - learned handling - adaptation

Fig. 3. A functional organ mapped to the (revised) aspects of the mediator coupled with the internalized routines on the three layers of activity

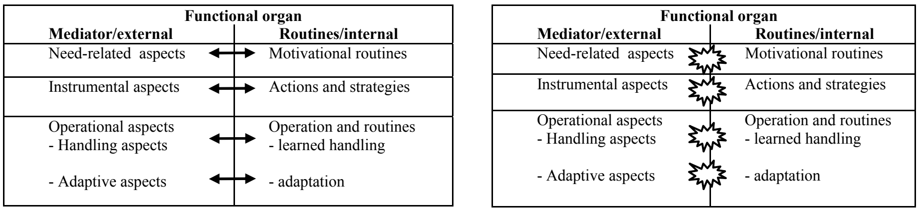

Fig. 4. Well-integrated and non-integrated functional organ

By mapping the way the mediator supports *intended* action possibilities and blocks other uses on the one hand, and the routines that the user is equipped with when exploring the mediator on the other (the *expected* action possibilities) on the four analytic layers of the functional organ, we explore and compare mediators in connection with the repertoires of actions and operations connected to them. Hence, we provide a better understanding of how one mediator may substitute another, and how well the substituting device may be integrated into the functional organs of the users (e.g. which effort it takes to do so)(figure 4).

A well-integrated functional organ is one where there is a fit as regards all four layers, whereas understanding problems of the integration focus on discrepancies at either layer (figure 4), or, as we shall see later, across layers. We talk about *breakdowns* whenever the integration stops working, and non-conscious routines become conscious actions (Bødker (1991). In the following, we will use our map examples to illustrate each layer of analysis of a functional organ.

3 Analyzing Functional Organs

Integration of a mediator into a functional organ clearly played an important role in the success or failure of solving a task on multiple levels of interaction: Groups who were familiar with a particular device had achieved a type of transparency in the interaction which allowed them to focus on the task/map specific issues, rather than on how to make the device perform in a certain way. Similarly, groups who were familiar with maps could focus on e.g. identifying different relevant waypoints rather than on interpreting the map; groups who were familiar with the local area visible through the window, could focus on verifying distance and direction by contrasting multiple visible waypoints and/or information on the map.

In the following, we will discuss the four analytical layers with examples from the map study, and for each level we will give examples of principal conflicts in the integration of mediators in functional organs. Such conflicts illustrate the fits and misfits of the functional organs on and between layers, and point to where misfits may occur when aiming to make ubiquitous substitution happen.

Need-related Fits and Misfits

Given a specific task or work domain, the need-related layer defines and sets the stage for the analysis. The need-related aspects refer to the question of *why* is there use for a given mediator. Our examples reflect the groups' attempts to solve the given assignments. We note that the need-related possibilities of a map also support e.g. being lost in a new city, looking for the way back to your hotel, where the motivational routines lie outside a very specific assignment.

In the map study examples, all assignments started with two people who had a joint assignment, access to a map-device and to the view out the window. They resulted in the two people agreeing on a target, common orientation, distance, etc. (the answer as it was defined by the assignment). The size of the map, and the way it was shareable affected how the two users would orient each other to the direction outside the window, on the map and in their common orientation.

Need-related misfits can be trivial; does the device match the needs of the user at all? But they can also be subtler; does the given implementation of the functionality needed match the actual needs? In our study, the tablet-pc provides tools for fine-grained distance measuring, but this does not match the need of the users, who were quite satisfied with a more coarse measure.

Instrumental Fits and Misfits

The instrumental layer relates to the question of what *is*, what *seems* or what *should* be possible to do with a mediator. Understanding these aspects of a mediator is fundamental for appropriating it as a functional organ. When analyzing ubiquitous substitution, this appropriation gets more complex, as there may be more mediators in play as background experience–mediators more or less appropriated as functional organs. It is necessary to know these individual mediators and understand what is normally possible, or assumed to be possible with them. To ascertain such assumptions, we require the mediator to clearly indicate the extent of its capabilities at the instrumental level.

We exemplify how the combination of functional organs can create instrumental conflicts by focusing on one group using the cell-phone map. During one task, the group members used routines for interaction with the phone developed in everyday use of cell phones (e.g. using menus, joystick). They focused on the task (in this case finding a specific street name) and the response they got from the phone map. The interaction with the cell-phone was fluid and unencumbered, and the understanding of the menu structures, and general information hierarchies associated with cell-phones was clear. However, the group experienced a breakdown despite a high degree of familiarity with the technical device and knowledge of maps in general: The group members expected to find a measuring tool for the map on the phone, and started looking for it by browsing through the menus before the researchers stopped them by telling them that feature did not exist.

Drawing upon the description of a functional organ in figure 4, we focus on the relevant layer of analysis (in this case the instrumental) to be able compare the different mediators and highlight any misfits found. The result is seen in figure 5.

Mediator:		Instrumental layer
Phone	E	Computational power
	I	
Map	E	Computational distance measuring
	I	No distance measuring available

Fig. 5. Misfit at the instrumental layer: a breakdown is caused by the expectations of a functionality (*expected action possibilities* E) that is blocked or not supported in the actual, implemented functionality (*intended action possibilities* I)

So, even though both the cell-phone and the map had become functional organs for the group members, the combination of the two had not. This was caused by their expectations of the functionality exceeded what was actually offered by the cell-phone map, given their current need for providing a distance measure (figure 5).

To avoid instrumental conflicts, it is necessary to understand the needs catalyzing the interaction: The need-related level frames what we do with the mediators on the instrumental level, and consequently plays an active part in deciding what to support and what to block. If the users had focused on the phone as a communicative device, the computational power might not have been the centre of the users' expectations as was the case in this example.

Handling Fits and Misfits

The handling and adaptive operational layers both refer to *how* an action is performed through a mediator. The handling layer covers acquired, once-conscious operations. Our examples show a variety of device-type dependent action-possibilities: E.g. leafing over the paper map using the number grid for orientation is an alternative to zooming and panning. None of those are natural. They have to be taught and trained; yet, they both lead to the same set of overall strategies. We have identified a high-level landmark-based identification strategy that is supported on all three devices, while the repertoires of operations used to carry the strategy through are clearly different. On the paper map, landmark-based identification is achieved through homing by placing hands and fingers on the map, indication of direction with hands on or over the map, adjusting the map either north-up or towards the target, and moving between map views by means of the number grid and leafing through the pages. In addition, several visual landmarks, e.g. churches and schools are marked on the map. On the tablet, landmark-based identification is achieved through homing, which in turn is achieved by panning/zooming (albeit not as precise as on the paper map or on the mobile phone), and indication of direction with pen or fingers over the screen. On the cell-phone, landmark-based identification is achieved through homing by means of the GPS-unit, panning/zooming for a wider or more detailed view, adjusting the map by moving the phone and one's own physical orientation, and handing over the device to support sharing. The well-integrated functional organ is, handling-wise, a matter of supporting routines for moving around on the map, panning, zooming, scaling, and for connecting the map to visible landmarks and streets as they appear in the view. With the existing map-devices, there is very little overlap between the necessary routines at the handling layer.

Our example of a handling misfit arised from the unfamiliarity of the paper map, experienced by particularly one group who did not recognize the grid-system for moving through maps, and consequently had a difficult time finding the right section of the map. This is in contrast to most other groups, who identified the relevant map section almost without verbalizing it, and flipped through the map pages while keeping focus on the identification task.

Mediator:		Handling layer	Adaptive operational layer
Paper	E		Leafing pages
	I		
Map	E	No perceived structure	
	I	Grid structure	

Fig. 6. Misfit with the grid structure: While the group can leaf pages they do not expect a support structure for this, and they do not recognize the grid structure even though it is visible

In this example (figure 6), the group members had no experience in recognizing the grid structure, and consequently no routines to rely on for getting to the part of the map they needed. There is no adaptive operational conflict; the group members were well aware of how one leafs through a book. However, the mere leafing of pages did not support the group members in recognizing the grid structure on the handling level. Thus, the group members experienced a handling breakdown that was overcome by getting clues from bystanders about how to decipher the encoding of the grid. On closer scrutiny, the grid structure provided its own clues on how to proceed, and, as such, the grid structure was not difficult to appropriate.

Handling conflicts originate from a lack of recognizability on an instrumental level; in this case, the inability to understand the grid structure of the map. Taken to the extreme, the lack of recognizability at the handling layer will make users unable even to create a new strategy to help them proceed, because strategies are constructed through fragments of routines based on recognizable elements on the instrumental level (Bedny et al, 2000).

The grid-structure misfit is an example of the importance of making the handling of a mediator explicit, in order to support the conscious appropriation of it, if the structure is unfamiliar to the users. This, however, must be done without compromising or blocking the automated use by those who recognize it.

Adaptive operational Fits and Misfits

In contrast to the handling layer, the adaptive operational layer describes our low-level responses to the physical conditions of and surrounding a mediator.

At this layer, an important issue is how maps are used when indicating direction, hence co-orienting the two participants. On the paper map it is sufficient to place one finger on home (their current location which is commonly known to the participants), and another in the relative direction on the map (figure 7). This pointing is supplemented with the movement of the finger back and forth.

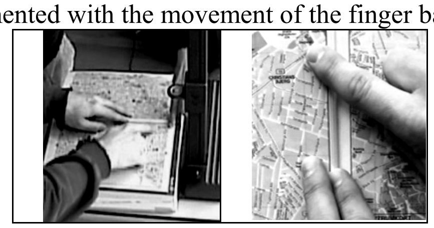

Fig. 7. North is in this direction–fingers give direction from "home" on the paper-map

Fig. 8. Giving directions on tablet-map

This kind of dynamic pointing is also used on the tablet (figure 8), where also a strategy unique for the tablet-PC is shown–holding the pen flat over the surface of the tablet in the direction of choice. As with the tablet, hand-waving is the most common way of indicating direction on the phone. This is supplemented with people holding their hand steady, upright pointing the fingertips in the direction of choice (figure 9). One group turns the cell-phone to align the map with the view in order to indicate direction. At this layer, the well-integrated map-device is a matter of turning, holding hands on, and handing over.

To illustrate the type of adaptive operational conflict, we use an example of how the groups measured distance on the tablet-map (figure 10). The tablet-map used a pen-like device that actually functions as a mouse. Even though all users knew how a mouse worked, and were told that the pen worked like a mouse, they ended up in situations where they tried to use the pen as a pen: They drew a line from point to point when wanting to measure distance, rather than what was supported by the map: To click on the end-points.

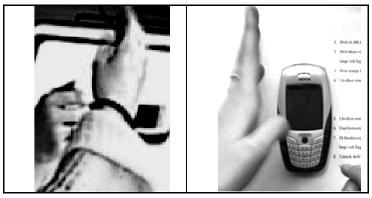

Fig. 9. Using hand to indicate direction on the cell-phone map

		Adaptive operational layer
Tablet	E	Drawing with pen
	I	Drawing and clicking with pen
Map	E	Drawing with pen
	I	Clicking with pen

Fig. 10. Conflict with the pen device

In this example, the pen suggested action possibilities that were blocked, because the tablet-map only supported measuring distance by clicking at end-points, and not through "drawing" by dragging a line from end-point to end-point.

The pen example clearly shows how using the pen as a mouse cannot be taught by instruction, but must be appropriated through use (by changing routines) because these belong to the adaptive operational aspects of the mediator.

Adaptive operational conflicts force the user to change routines, possibly with the consequence of causing a ripple effect, shaking the basic foundations of other functional organs involving the same or similar mediators.

All together now!

To fully spell out the analytic power of the functional organ, it is essential to bring the layered analysis back together again. The example of distance measuring on the tablet-map shows how connections between layers need to be addressed: The tablet map has a dedicated tool for measuring distances between two points or along a series of segments. This gives a very accurate measure of distance in contrast to the routines that users apply on the paper map, and helps compensate for the dynamic map scale. As the scale changed with zooming, the distance-measuring tool provides an immediate and accurate mapping of scale to the map segment in focus. The measuring distance tool supports what the users are trying to accomplish in terms of needs; it is an externalization of a whole range of routines developed through other mediators and collapsing routines from several different levels, and, as such, it is a quite complex mediator in it self. However, the tablet map fails to support several groups in distance measuring because of the ambiguity of the pen-like input. One of the underlying assumptions of the tablet map is that the pen-shaped device is recognized as a mouse rather than a pen (which, for other tasks are unproblematic). This is a problematic assumption because it forces the users to disassociate the physical shape of the input device from the act of using it.

To target what mechanisms in the mediator that help and prevent development of the functional organs, we turn to Bærentsen & Trettvik's (2002) question of how exploration of the intended use may be supported, and how some of the possible, yet less desirable uses may be blocked? Evidently, the possible uses are numerous, which is a methodological problem. The best indicator to us in our map study of possible and desirable uses, is what uses the groups make of the other map devices. Obviously, there are many more, some of which are outside our limited setup. But even within this framing, the possibilities are virtually limitless. In figure 11 we summarize examples of the supporting and blocking mechanisms we have seen in the three map-devices.

	Paper-map	Tablet-map	Cell-phone map
Support of intended uses	Homing with fingers Coarse-grained distance measure Exploration by leafing Grid-based navigation	Fine-grained distance measuring Exploration of map through zooming and panning by pointing and clicking	Homing on home by GPS
Blocking of possible uses	Distance measure over large distances	Homing–no fingers on	Homing on target–no fingers on Distance measure

Fig. 11. Example mechanisms for supporting and blocking

4 Ubiquitous substitution

We now address the challenge of ubiquitous substitution–substitution that does not abandon the old mediator, but supports the ongoing re-substitution of the mediators. There are two motivations for doing so: a desire to perform direct comparison of mediators vis-à-vis a certain purposeful activity, and an analysis of a design space of existing mediators with the focus of building a new one. In terms of our examples, we are interested both in what it take to become fluent users of several existing maps (creating more complex functional organs), and in approaching the design of a new map-device (to be appropriated as a functional organ).

As we have shown, many elements must be in place for creating a well-integrated functional organ: There must be a match between the mediator and the routines at all four layers. It takes little to disturb this harmony–we have seen that a paper map is a well-integrated functional organ to most groups, but that it only takes a breakdown at one layer, e.g. the lack of experience with the grid structure, to disturb this. Even worse, the cell-phone map is neither map, nor PC, which causes a lot of misfits. When functional organs become integrated into a new one that supports ubiquitous substitution, and e.g. lets the user apply both a paper-map and a tablet-map fluently for a task, the case becomes even more complex. Here, it is important that the use of one mediator does not disturb the understanding and routines connected to another. Again, we see this at all layers - learning to use the pen as a mouse - may not only be difficult, it may actually also prevent the future use of the mouse; getting used to scrolling in one manner may be disturbed by the introduction of an application that scrolls differently. In Bødker & Bøgh Andersen (2004), we see an example where historical generations of machine telegraphs are used on a ship bridge, as supplements to one another. Thus, it becomes essential to study the current repertoires of actions, operations and handling aspects as the starting point for new design. This is not to directly aim to replicate these in the new mediator, but rather to understand what minimal sets of action possibilities are necessary, which to be supported, and which to be blocked.

In a direct evaluation of how the tablet-map as new mediator may substitute the paper-map which is part of an existing functional organ, we found that such substitution becomes a matter of

- fitting into the needs of the user (though not as a direct substitution of one set of motivational elements with another).
- being understandable in terms of what it does or does not offers to the user; a minimal set includes visible scale, visible direction, and means for navigation.
- supporting (minimal) sets of routines at the handling level, so that e.g. the necessary strategies can be planned and carried out; at the same time, it may block other action possibilities.
- supporting adaptability (e.g. that all map-devices need to be turn-able to face north-up).

When looking at how navigation is supported on paper versus on tablet–a direct comparison on the handling level–we compare the grid-structure with panning and zooming through pointing and clicking. Those who have been taught the grid structure handle this well, and those, who were not, encounter problems. Panning through pointing and clicking instantly became routine (through instant feedback from the tablet). Thus, as an example of the minimal sets of routines to support, we would go for panning and zooming without making use of the grid structure known from paper maps. Yet, a new map-device would benefit from offering itself more to putting and holding hands on the map, and borrowing visible building-landmarks as they are marked out on the paper map.

In our design-oriented analyses, we see a move of focus away from the handling, which previously in HCI has been the predominant focus (e.g. in GOMS and keystroke level analyses (Card et al. 1980)), and towards the instrumental one on the one hand, and the adaptive operational one on the other. This obviously does not mean that the handling will or should disappear from consideration. If that happened, every user would be faced with a device where every step, except the basic holding and turning, would need to be planned and consciously carried out, i.e. the total breakdown. At the other extreme, handling could be highly standardized, just like car manufactures apply strictly standardized support for handling, which means that anybody can basically jump into–and securely drive–any car. We do not argue for any of those solutions. Instead, we argue that it is essential to identify and support minimal sets of routines at the handling level (e.g. the ones needed for using a map, together with the ones of using a cell-phone), so that the necessary strategies can be planned and carried out; at the same time other action possibilities may be blocked. It is equally essential that the action possibilities are recognizable as action possibilities in order to be included in strategies that get transformed into new routines through use.

This way of thinking gives indicators as to how to design a new functional organ, e.g. a map-device, yet the actual implementation of e.g. pan and zoom on a new technology depends on the capabilities of the technology in question, and must ultimately be evaluated in use like any other interaction design.

With this paper, we have taken the first step in confronting the challenges of ubiquitous interaction; we have provided a theoretically based foundation for describing and understanding *ubiquitous substitution* by analyzing interaction across different technologies in terms of mediators and functional organs intended and expected use.

Breaking mediators down into four analytical levels has provided us with a strong analytical tool that, through examples from a recent case study, enabled us to analyze interaction, and pinpoint exactly from where trouble stem. This points towards development of new mediators from the perspective of minimalist handling.

5 Discussion

We have chosen to focus entirely on the topic of substitution of mediators, while in many ways ignoring the many kinds of complexity surrounding the use of the particular mediators. We have for instance largely ignored the juxtaposition of mediators (Bertelsen & Bødker, 2002), i.e. the combination of address register with the paper map, and even the view out the window, or the binoculars that one might use to enhance the view. We have ignored the web of activities and mediators (Brodersen & Kristensen, 2004) that surrounds the substituting mediators in general, and the way-finding situations in particular. Nevertheless, with the proposed framework, we provide a concrete basis for designing within "webs of technology" (Nielsen, 2002). We have not ignored these elements because they are irrelevant, or because the theoretical framework does not deal with them. On the contrary, the framework reflects those exact ideas, and our only reason is to reduce the complexity of the analyses.

The mediator and the functional organ are the centrepieces of our analyses. The mediator is everything, from a simple cursor shape applied for a particular purpose in a design, a scrollbar, the Windows desktop, to other complex arrangements. The framework helps us spot misfits, breakdown in any of these. This is indeed a strength and a weakness. A strength because we escape the separation of hardware from software, which to the best of our belief matters little to the user, while maintaining a comparison across designs. Also, because we have seen that a tiny problem in one element may jeopardize the entire functional organ. The weakness is obviously that we inherit the problem from activity theoretical HCI of limiting the analysis (Bødker 1991). By taking up the challenge of ubiquitous interaction, we have, however, gone a long way towards analysis and designs that cross interaction styles.

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