User Experience Starts at the Keystroke Level: The Model of User Experience (MUX)

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Abstract. In the last years the emotional impact of artifacts became more and more interesting to the field of human-computer interaction research. Despite many models that describe factors of user experience (UX), most of them are of a descriptive nature. In contrast, we propose a theoretical approach, the model of user experience (MUX) that offers an explanation for the emergence of UX starting from the very first interaction steps. Additionally, we present empirical results that support these assumptions of our theoretical approach that were under investigation. In detail we found that affordances as well as standard signals foster users performance on a small time scale (up to 3 sec.). However, these small changes affected peoples UX. Hence we conclude that it is a fruitful approach to start investigating UX on a keystroke level.

Keywords: user experience, theoretical model of user experience, user experience design.

1 Introduction

The research focus of human-computer interaction (HCI) has shifted from usability research towards user experience (UX) in the recent decade (e.g. [1]). However, the concept of (UX) is still hard to capture (e.g. [1], [2]). Literature presents numerous theoretical models that consider many aspects of UX like instrumental as well as non-instrumental interaction aspects [3], hedonic and pragmatic qualities of products [4], levels of interactions [5] or stages of HCI [6]. However, most of these models are quite abstract when it comes to processes that yield UX. They rather describe drivers, factors, contexts etc. that might contribute to an understanding of the construct. In contrast to these approaches, we suggest that studying UX does not need to exclusively focus on high-level descriptions. Numerous well-known psychological concepts from different domains can be deployed to describe how features of the environment relate to user behavior and experience. The Model of User Experience (MUX) integrates such concepts into one comprehensive framework. Moreover, it defines whether its constructs are applied to the environment or the person. In addition, the model proposes possible measures for each of the implemented concepts. Focusing on

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the instrumental qualities of an artifact, the MUX emphasizes the relation between system properties and two central aspects of UX, Ease of Use [7] and Joy of Use (e.g. [8]). In fact, the MUX is based on the assumption that there are features of a technical artifact like affordances (e.g. [9], [10]), constraints [10], the attraction of attention [11] or mappings [10] that trigger cognitive processes which in turn evoke Immediate Interactive Behavior [12] and Ease of Induction [13], both yielding positive UX. Integrated in the MUX, these single concepts connect to a theoretical chain that attaches the design of technical devices on one hand with important aspects of UX on the other. Thereby, the MUX proposes that the very first interaction steps (i.e. actions of about 300ms to 3 sec.) already elicit UX. So far, several empirical investigations have shown support for the theoretical assumptions of the Model of User Experience (e.g. [13-15], [11]). However for one aspect of the MUX (i.e. affordances) no clear statement about the model assumptions was reached (cf. [15]). Therefore, the present research addresses this concept and investigates whether affordances elicit Immediate Interactive Behavior (IIB) as proposed by the MUX. In turn, if more IIB is observable subjects should report more positive user experience.

1.1 Affordances and Signals

Gibson suggested that we do not focus on single object properties when perceiving an object in real life [9]. Instead, one perceives what the object affords to oneself. Following Gibson “An affordance is an invariant combination of variables […]” like color, surface structure or shape ([9], p.134). To specify affordances one needs to consider specifications of the environment and the observer (e.g. background knowledge). Hence an affordance relates properties of the environment to perceived action possibilities for the observer [9]. Based on Gibsons work, Norman transferred the concept of affordances to the human-computer interaction domain (cf. [10]). In line with Gibson, Norman proposed that affordances provide knowledge to the operation of things. However in contrast to Gibson, Norman stated that affordances are on hand if users of technical artifacts are enabled to apply their previously gained knowledge to the current interaction [10]. Maybe the most prominent examples for the role of affordances in interface design are Norman doors. Using different types of door handles, Norman pointed out that the ease of use regarding the operation of doors mainly depends on the application of affordances [10]. For example, in case the door needs to be pushed and the door handle affords pushing, people could easily operate the door. In line with Norman, we think of affordances as pointed out by Greeno: “In any interaction involving an agent with some other system, conditions that enable that interaction include some properties of the agent along with some properties of the other system. [...] The Term affordance refers to whatever is about the environment that contributes to the kind of interaction that occurs.” ([16], pp. 338). In line with the Gibsonian idea of affordances [9], we assume that affordance congruent behavior is fast and unconscious.

Till now, affordances have been intensively studied and successfully implemented in design (e.g. [17]). For example, based on the Model of User Experience (MUX) Vogel et al. varied the affording character of a graphical user interface (high vs. low affording in terms of the goal of the task) and quantified subjective experience, usability (subjective, objective), utility and acceptance regarding two systems [11]. They found that an interface that strongly afforded behavior, which was leading to the goal accomplishment, resulted in higher ratings of subjective usability and utility as well as a more positive mood. In contrast to affordances, artificial indicators are conveyed culturally and their symbolic meanings have to be learned explicitly. Artificial visual indicators are often described as signs or symbols [18]. Following Petocz, signs are arbitrary cues that convey a pre-defined message [18]. Thus, signs and symbols are not affordances [19]. "They are examples of the use of a shared and visible conceptual model, appropriate feedback, and shared, cultural conventions." ([19], p. 41). Arrows are one type of symbols, defined as a line with one end marked, inducing an asymmetry (cf. [20]). Arrows have a diversity of semantic roles, e.g. moving direction, physical change, labeling, focusing attention, which have to be learned and distinguished in a given situation [20].

1.2 Immediate Interactive Behavior (IIB)

The concept of IIB "[…] entails all adaptive activities of agents that routinely and dynamically use their embodied and environmentally embedded nature to support and augment cognitive processes." ([21], p.33). That means the users' interaction with the environment utilizes simple interaction routines (i.e. tapping or pressing) which are fast (1/3 to 1 second), interaction-intensive and without cognitive effort [21]. Their application alters the cognitive system as well as the environment the agents are acting in [21]. Hence, the occurrence of IIB shows the expansion of cognition in real time. Its application impacts subjects' motivation due to the experience of their ability to make progress. Furthermore people have feelings of competence based on the successful application of their knowledge [14]. Empirical evidence from cognitive psychology and cognitive ergonomics support the assumptions of Neth et al. [21] with respect to IIB [12]. For example Neth and Payne investigated whether interaction fostered the resolution of counting tasks (i.e. counting coins) [12]. Subjects that were able to touch and move the coins were faster and more accurate in solving the counting task, compared to subjects that were only allowed to look at the arrangement of coins. In cognitive ergonomics Drewitz and Brandenburg published the Model of User Experience (MUX), embedding IIB as key concept [14]. This model lists factors that structure the environment in a way that it is likely to afford IIB. As shown in figure 1, the MUX proposes that the ideal environment is structured to support IIB, which conceptually captures the interaction of people with their environment on a very small time scale (see also [14]). However, the ideally structured environment always depends on the interaction goal.

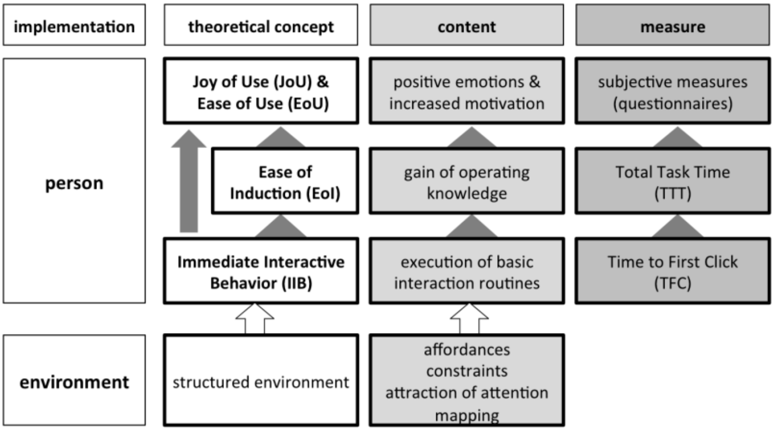

Fig. 1. The model of user experience (MUX)

1.3 Research Objectives

So far, empirical investigations did not yet deliver clear evidence for the aspect of affordances (see [15]). Therefore the present study investigates the role of affordances for the emergence of UX on a multi-touch table. Based on the MUX it can be assumed that the presence of affordances does facilitate subjects' performance and lead to more positive UX compared to their absence. To demonstrate that affordances do affect IIB and UX more than standard signals, we included the presence or absence of arrows as standard signals in the experiment as well (see also [15]). Since arrows are a somewhat well learned signal, their presence should increase IIB and thus elicit a more positive UX compared to their absence. However, the positive effect of affordances should be larger than the effect of signals. Including both factors in a 2x2 between subjects design, it was possible to test the single and joint effects of both types of information on subjects' performance and experience.

2 Method

2.1 Subjects and Material

A total of N = 48 multi-touch table novices (age: M = 30.5, SD = 9.2, 27 female/21 male) voluntarily participated in the experiment. The multi-touch interface consisted of a text box presenting the actual task, a working environment and three blue squares on the right hand side (see Fig.2). These three objects had to be manipulated using different gestures. Subjects' task was to execute the right gestures for rotating, scaling and cutting a blue square (see Fig.3). In the experiment, all subjects saw (light) touch areas indicating where they had to place their fingers. The arrows were presented to the subjects in the corresponding group, only. Affordances were defined as an initial movement of the object into the direction of gesture execution. For example, for scaling a blue object, subjects put their fingers in the lighted corners of the blue square.

As soon as both fingers were placed in opposite corners, the object started to gradually enlarge itself to 130 percent of its original size. Then it shrunk back to the original size. This movement was repeated as long as participants started to execute the gesture.

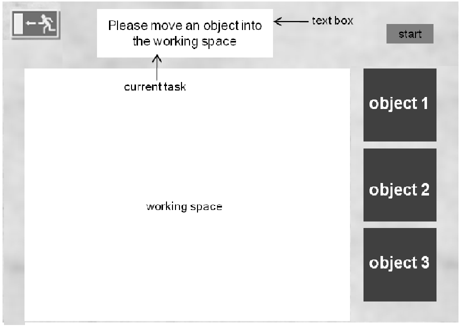

Fig. 2. Experimental environment presented on the multi-touch table

Additionally, participants were asked to fill in two questionnaires, the NASA-TLX [22] and the QUESI [23] to assess their subjective experience. The NASA questionnaire assesses subjective stress and strain, whereas the QUESI indicates feelings of ease of use.

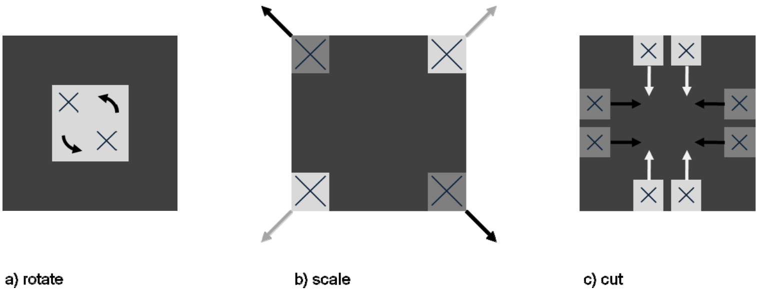

Fig. 3. Visualization of the three gestures. In the experiment, all subjects saw (light) touch areas. The arrows were presented to the subjects in the corresponding group, only. Crosses are shown for visualization purposes.

2.2 Procedure and Experimental Design

First of all, subjects familiarized themselves with the multi-touch table in an exercise trial. In this first trial, participants tested the movement of objects and the multi-touch surface sensitivity. Therefore, subjects were asked to move one of the three squares from the right hand side (see Fig.1) into the working space. Now participants received the instruction that their task was to execute the three different gestures: rotate, scale and cut (see Fig. 3a-c) three times. Hence each subject accomplished three trials, each of them containing all three gestures. The mapping of gestures to objects was randomized over subjects and trials. Hence it was impossible to associate an object with a special gesture. For each manipulation of a square, participants dragged one of them into the middle of the working space. Then, they read the current task in the interfaces text box. If participants felt that they understood the task, they pressed the start button and initiated the gesture execution. At the end of each trial all participants filled in the NASA-TLX [22]. After finishing the experiment they were also asked to complete a general questionnaire gathering demographic variables and the QUESI [23]. The entire experiment took about 30 minutes. Subjects were randomly assigned to one of the four experimental groups.

In total, two independent variables with two steps each were manipulated in a between-subjects design: affordances (present and absent) and signals (present and absent). Moreover three gestures (rotate, scale, cut) as well as three trials (T1, T2, T3) were manipulated as within-subjects factors. Objective (Time to First Click, TFC and Total Task Time, TTT) as well as subjective (NASA-TLX and QUESI) data was assessed. Time to first click was defined as period between subjects pressing of the start-button and the recognition of both fingers in the respective highlighted areas of the object (see Fig.3). Total task time was operationalized as time between participants pressing of the start-button and the automatic disappearance of the object after task completion.

3 Results

3.1 Objective Data

For the analysis of the behavioral data a mixed effects MANOVA with repeated measures was computed. The three gestures (cut, rotate, scale) entered the analysis as within-subjects factor. Affordances (present or absent) and signals (present or absent) were between-subjects factors. The three time points (T1, T2 and T3) were included as repeated measures. Both sources of behavioral data (Total Task Time, TTT and Time to First Click, TFC) were dependent variables. Bonferroni adjusted post-hoc tests and effect sizes (f) after Cohen are reported if applicable [24]. Effects with the size of $0.10 < f < 0.25$ are regarded as small, $0.25 < f < 0.40$ as medium and $0.40 < f$ as large. Due to limitations of space, the presentation of results will focus on most important effects only.

Regarding the results of the analysis, we found medium and large main effects of gesture (TFC: $(2,88) = 3.81$, $p = 0.02$, $f = 0.29$; TTT: $F(2, 88) = 7.91$, $p < 0.001$, $f = 0.42$) and time (TFC: $F(2,88) = 46.33$, $p < 0.001$, $f = 1.02$; TTT: $F(2, 88) = 9.69$, $p < 0.001$, $f = 0.46$) on both measures. With respect to the gestures, subjects showed a tendency to be slower in executing the cutting gesture compared to the other two gestures (TFC & TTT: $ps < 0.10$). Times did not differ for rotate and scale (TFC: $p = 1.00$; TTT: $p = 0.93$). In addition, participants significantly decreased in TTT and TFC for the first to the second trial (TFC & TTT: $ps < 0.01$). Further improvement from trial two to trial three was only significant for TFC ($p < 0.01$). With respect to the hypothesis, analysis revealed no main effects for affordances and signals (TFC & TTT: $Fs < 1.52$, $ps > 0.22$). However, the joined effect of both factors significantly impacted TFC ($F(1, 44) = 7.19$), $p < 0.01$, $f = 0.40$) and showed a tendency for TTT

(F(1, 44) = 3.02), p < 0.08, f = 0.25). As shown in Figure 3a, participants were fastest (regarding TTT) if both cues (affordances and signals) were present. This effect was not as strong for TFC (see Fig.3b). Here, two combinations revealed fastest TFCs: affordances and signals present and both absent.

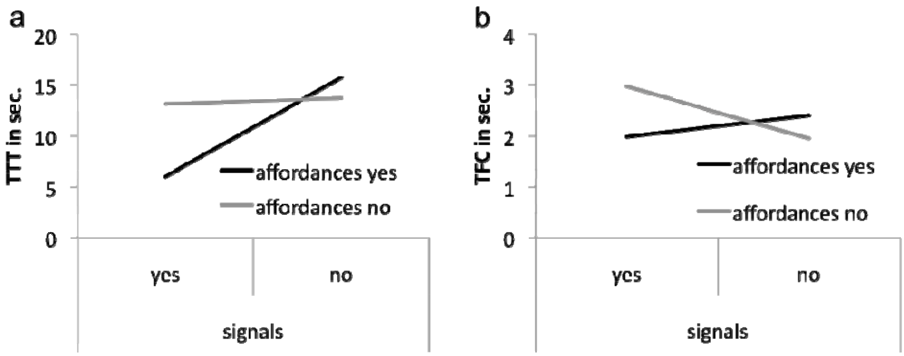

Fig. 4. Results regarding a) Total Task Time (TTT) and b) Time to First Click (TFC) in sec. for all combinations of affordances and signals

3.2 Subjective Data

Due to different points of measurement for the NASA-TLX (T1, T2, and T3) and only one point of measurement for the QUESI, two analyses of variance were computed for the subjective data. First, an ANOVA with repeated measurement over all trials was performed revealing the effects of affordances, signals and time (T) on subjective demand and effort (NASA-TLX). Second, an ANOVA was computed analyzing the influence of affordances and signals on intuitive use of the system (QUESI). Due to the massive amount of significant results, only data that are relevant for the hypothesis are reported in detail. With respect to subjective demand and effort (NASA-TLX), analysis revealed significant effects of affordances on the general score (F(1, 43) = 4.38, p = 0.04, f = 0.31) as well as on the subscales mental and temporal demand (Fs > 3.48, ps < 0.07, fs > 0.29). In contrast, signals only showed a tendency for the NASA-TLX subscale mental demand (F(1,43) = 3.09, p = 0.09, f = 0.29). Moreover, in line with the objective data the interaction of both factors effected the NASA – TLX general score (F(1,43) = 4.66, p = 0.04, f = 0.33) as well as the subscales mental demand, frustration and performance (Fs > 3.47, ps < 0.07). Figure 4 visualizes the main effect of affordances and the interaction effect of both factors on the general NASA-TLX score. It is visible that the presence of affordances lowers subjective feelings of strain. Moreover, subjects indicated lowest stain values if affordances and signals were present. In accordance with the impact of affordances on the scores of the NASA-TLX, analysis revealed tendency of affordances on the QUESI subscale goal attainment (F(1,43) = 3.30, p = 0.08, f = 0.27). Moreover the interaction of both factors impacted the general QUESI score (F(1,43) = 8.87, p < 0.01) as well as the subscales, goal attainment, learning effort, familiarity and subjective error rate (Fs > 4.79, ps < 0.02).

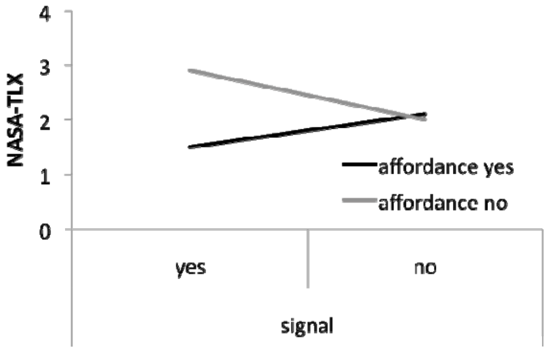

Fig. 5. Significant two-way interaction of affordances and signals and its effect on subjective feeling of demand (NASA-TLX)

4 Discussion

The aim of this study was to empirically demonstrate which form of assistance (affordances or signals) helps users the most and elicits highest UX ratings while interacting with a novel technical device. Results demonstrated, that there was no clear-cut advantage of either form of help. Instead, performance data coherently suggested an interaction of both factors. Thus the effect of affordances is not independent from the effect of signals. Based on the performance data, one could conclude that affordances and signals might be instances of the same category, which are operational clues. Another explanation might be found in the type of signals that were used in the experiment. Arrows that indicate a direction to move something are one of the most common hints in modern computer programs. Therefore subjects might have over learned their semantic meaning. If this is the case, natural indicators like affordances and well-learned signals might elicit the same behavior of subjects, although this behavior relies on different mechanisms. In the present work, affordances were implemented as object movements that corresponded to the execution of the gesture. Therefore these movements might have fostered subjects gesture execution on a natural basis. Participants might just have followed the objects movement that was already started. However, in terms of the arrows it is plausible to assume that these over learned symbolic cues triggered procedural knowledge, which is fast as well (cf. [25]). Hence, the group that saw both manipulations was able to rely on two different mechanisms. Thus, this group was fastest. Subjective data mainly supports this interpretation. As for the objective data, most subjects indicated less strain and more intuitive use if both, affordances and signals were present. Nevertheless, we also obtained main effects for affordances and signals on the mental demand subscale of the NASA-TLX. Hence the presence of each of them increases subjective wellbeing. Comparing the effects of affordances and signals, there is no clear picture favoring either one of them. However affordances showed a slightly larger impact on subjective measures than signals.

To sum up, the results partially support the assumptions of the Model of User Experience (MUX, [14]). As expected, affordances did enhance performance and fostered positive UX. However their effect was dependent of signals being present. The persistent interaction of both factors replicates results of Zinn and Brandenburg [15]. In their study subjects also indicated most positive UX if affordances and signals were presented at the same time. In addition, some limitations of the current experiment might have contributed to the results. Firstly we used a very simplistic experimental setting. Executing simple gestures with blue squares does not resemble real world tasks and might have channeled subjects' attention to the few things that were visible to them. Secondly large effects of gesture and time indicate that peoples' performance strongly changes over time and gesture familiarity (see also [15]). Of course ANOVA analysis revealed the effects across the experiment. Still, results might become clearer, if subjects gather more experience with the device. Thus upcoming experiments should go on to more realistic settings and tasks.

References

1. Hassenzahl, M., Tractinsky, N.: User experience – a research agenda. Behavior and Information Technology 25, 91–97 (2006)
2. Hassenzahl, M.: User Experience und Experience Design – Konzepte und Herausforderungen. In: Brau, H., Diefenbach, S., Hassenzahl, M., Kohler, K., Koller, F., Peissner, M., Petrovic, K., Thielsch, M., Ullrich, D., Zimmermann, D. (eds.) Usability Professionals, pp. 233–237. Fraunhofer Verlag, Stuttgart (2009)
3. Thüring, M., Mahlke, S.: Usability, aesthetics and emotions in human-technology interaction. International Journal of Psychology 42, 253–264 (2007)
4. Hassenzahl, M.: The thing and i: understanding the relationship between user and product. In: Blythe, M., Overbeeke, C., Monk, A., Wright, A. (eds.) Funology: From Usability to Enjoyment, pp. 31–42. Kluwer, Dordrecht (2003)
5. Norman, D.: Emotional Design: Why we love or hate things. Basic Books, New York (2004)
6. Pohlmeyer, A.E., Hecht, M., Blessing, L.: User Experience Lifecycle Model ContinUE [Continuous User Experience]. In: Lichtenstein, A., Stoessel, C., Clemens, C. (eds.) Der Mensch im Mittelpunkt technischer Systeme. 8. Berliner Werkstatt Mensch-Maschine-Systeme, pp. 314–317. VDI, Düsseldorf (2009)
7. Davis, E.D.: Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. Management Information Systems Quarterly 13, 319–340 (1989)
8. Norman, D.A.: Emotion & Attractive. Interactions: New Visions of Human-Computer Interaction 9, 36–42 (2002)
9. Gibson, J.: The Ecological Approach to Visual Perception. Houghton Mifflin, Boston (1985)
10. Norman, D.A.: The Psychology of Everyday Things. Basic Books, New York (1988)
11. Vogel, M., Brandenburg, S., Drewitz, U.: Zur Gestaltung graphischer Benutzungsschnittstellen: Einflussfaktorenfür das Nutzererleben. In: Eibl, M. (ed.) Mensch & Computer 2011: überMEDIEN|ÜBERmorgen, Oldenbourg, München (2011)
12. Neth, H., Payne, S.J.: Interactive coin addition: How hands can help us think. In: Carlson, L., Hölscher, C., Shipley, T. (eds.) Proceedings of the 33rd CogSci, pp. 279–284 (2011)

13. Brandenburg, S., Drewitz, U., Thüring, M., Minge, M., Brune, T.: Touch me if you can - Immediate Interactive Behavior alsBedienkonzeptfürMultimediageräte. In: Lichtenstein, A., Stößel, C., Clemens, C. (eds.) Der Mensch im Mittelpunkt technischer Systeme. 8.BerlinerWerkstatt Mensch-Maschine-Systeme, vol. 22, pp. 105–106. VDI Verlag GmbH, Düsseldorf (2009)
14. Drewitz, U., Brandenburg, S.: From design to experience: Towards a process model of user experience. In: Lin, J.C., Lin, D.M., Chen, H. (eds.) Ergonomics for all: Celebrating Ppcoe's 20 years of excellence: Selected papers of the Pan-Pacific Conference on Ergonomics, pp. 117–122. Taylor & Francis, London (2010)
15. Zinn, J.M., Brandenburg, S.: Support of Gesture Learning for MultiTouch Interfaces. In: Schmid, S., Elepfand, M., Adenauer, J., Lichtenstein, A. (eds.) Reflexionen und Visionen der Mensch-Maschine-InteraktionAus der Vergangenheitlernen, Zukunftgestalten 9. Berliner Werkstatt Mensch-Maschine-SystemeZMMS Spektrum Band, vol. 33, pp. 134–142. VDI Verlag, Düsseldorf (2011)
16. Greeno, J.G.: Gibson's Affordances. Psychological Review 101, 336–342 (1994)
17. Galvao, A.B., Sato, K.: Affordances in product architecture: Linking technical functions and users' tasks. In: Proceedings of DETC. University of Michigan, ASME (2005)
18. Petocz, A., Keller, P.E., Stevens, C.J.: Auditory warnings, signal-referent relations, and natural indicators: Re-thinking theory and application. Journal of experimental psychology: Applied 14, 165–178 (2008)
19. Norman, D.A.: Affordance, conventions, and design. Interactions 6, 38–43 (1999)
20. Kurata, Y., Egenhofer, M.: Semantics of Simple Arrow Diagrams. In: Barkowsky, T., Freksa, C., Hegarty, M., Lowe, R. (eds.) AAAI Spring Symposium on Reasoning with Mental and External Diagram: Computational Modeling and Spatial Assistance, pp. 101–104. AAAI Press, Palo Alto (2005)
21. Neth, H., Carlson, R.A., Gray, W.D., Kirlik, A., Kirsh, D., Payne, S.J.: Immediate Interactive Behavior: How Embodied and Embedded Cognition Uses and Changes the World to Achieve its Goals. In: McNamara, D.S., Trafton, J.G. (eds.) Proceedings of the 29th Annual Conference of the Cognitive Science Society, pp. 33–34. Texas, Austin (2007)
22. Hart, S.G., Staveland, L.E.: Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. Human mental workload. In: Hancock, P.A., Meshkati, N. (eds.) Human mental workload - Advances in psychology, vol. 52, pp. 139–183. North-Holland, Amsterdam (1988)
23. Mohs, C., Hurtienne, J., Scholz, D., Rötting, M.: Intuitivität - definierbar, beeinflussbar, überprüfbar. In: Useware 2006 - VDI Berichte, Nr. 1946, pp. 215-224. VDI-Verlag, Düsseldorf (2006)
24. Cohen, J.: Statistical power analysis for the behavioral sciences. Erlbaum, Hillsdale (1988)
25. Anderson, J.: KognitivePsychologie. Spektrum Akademischer Verlag, Heidelberg (2001)