The touch appeal: Why touching things is so popular in Human-Computer Interaction

Stefan Brandenburg & Nils Backhaus
Technische Universität Berlin
Germany

Abstract

This paper utilizes a theoretical framework (the model of user experience) to describe the appeal of touch interfaces. Therefore it starts with a brief discussion of the framework. In the second part it presents empirical evidence undermining the theoretical claims. Study results show that theoretical claims are partially supported by the data. The findings are in line with previous research. The paper concludes that the touch appeal derives from the structure of the (task) environment.

Introduction

Touch-sensitive graphic user interfaces are implemented in a wide range of technical artefacts. However, Human-Computer Interaction researchers still try to explain why this type of interaction is so popular.

For example, Drewitz and Brandenburg (2010) proposed a framework (model of user experience) that relates characteristics of interfaces to feelings of ease of use and joy of use (Davis, 1989). Based on this framework, touch interfaces structure the environment in which an operator solves his tasks. They address mechanisms like affordances, constraints, etc. In turn, these mechanisms foster the elicitation of immediate behaviour and, finally, both feeling of ease of use and joy of use (Drewitz & Brandenburg, 2010; Brandenburg et al., 2013). Therefore, based on Drewitz and Brandenburg (2010) touch interfaces are appealing because of their structured environment.

The structured environment of touch interfaces

Based on the model of user experience, all environments are structured with respect to four characteristics: affordances, constraints, attraction of attention, and mapping (Drewitz & Brandenburg, 2010).

Affordances provide action opportunities. In 1979 Gibson suggested that people do not just perceive an object. Instead, they additionally assess what an object affords to them. Based on peoples' background knowledge and motivations, the same object has different affordances. Therefore, affordances are neither a property of an object, nor a property of the artefact. They emerge depending on both, the properties of the artefact (i. e. weight, structure) and the observer (i. e. knowledge and motivation).

In D. de Waard, K. Brookhuis, R. Wiczorek, F. di Nocera, R. Brouwer, P. Barham, C. Weikert, A. Kluge, W. Gerbino, & A. Toffetti (Eds.) (2014). Proceedings of the Human Factors and Ergonomics Society Europe Chapter 2013 Annual Conference. ISSN 2333-4959 (online). Available from http://hfes-europe.org

Hence, learning changes affordances as soon as it changes the background knowledge of learners. In turn, to specify affordances one needs to consider specifications of the environment and the observer. An affordance relates properties of the environment to perceived action possibilities for the observer (Gibson, 2000). In line with Gibson (1979), Norman (1988) proposed that affordances provide knowledge to the operation of things. He stated that affordances are on hand if users of technical artefacts are enabled to apply their previously gained knowledge to the current interaction. In line with Norman (1988), we think of affordances as pointed out by Greeno (1994, p. 338): "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." In line with the Gibsonian idea of affordances, we assume that affordance-congruent behaviour is fast and unconscious. Till now, affordances have been intensively studied and partially successfully implemented in interface design (e. g. Vogel et al., 2011).

Having a lot of competing affordances, the user can only follow one of them at a time. Therefore the design of an artefact has to be constrained. In human computer interaction constraints are limitations in the interface or the operational concept of the artefact. For example, limiting the number of actions that can be executed at a time increases the chance that a user accomplishes his interaction goal. Norman (1988) pointed out that the users' mental model should map to the designers model of an artefact and both communicate over the system image. Therefore it is important that the environment that is created by the artefact maps to the users knowledge in terms of appearance and functionality (cf. Norman, 1988).

Finally, attraction of attention means that system designers apply (visual, auditory, etc.) cues to attract the user's attention. Moreover, designers use these cues to guide the user's attention towards subsequent interaction steps. For example, Vogel et al. (2011) found that using colour to guide the user's attention through the interaction fostered interaction and increased positive user experience. They concluded that highlighting subsequent interaction steps relieves users working memory and thus decreases cognitive strain.

Touch interfaces met most of these characteristics. Since the operating principle of these interfaces mainly relies on (simulated) 3D Buttons, the affordance of pressing them is very prominent (cf. Vogel et al., 2011). Moreover, as Vogel et al. (2011) also pointed out, semantically meaningful icons additional foster affordance congruent behaviour. However, touch interfaces are also heavily constrained in terms of hardware. They mostly provide a large screen almost without any hardware buttons. Thus the number of competing affordances (pressing hard- or software buttons) is reduced. Regarding their software, touch interfaces are also very constrained. Due to the minimum size of software buttons and limited screen size only a limited amount of action properties can be presented (cf. Backhaus & Brandenburg, 2013). This reduces the number of competing affordances as well. If designers attract the attention of users and map the interface structure to the user's mental model, the effects of the structured environment on behaviour and his or her experience might be positive.

Effects of the structured environment on behaviour and experience

According to the framework of Drewitz and Brandenburg (2010) the structure of the environment determines the degree of users Immediate Interactive Behaviour (Neth et al., 2007); knowledge acquisition (Ease of Induction Brandenburg et al., 2009) and feelings of ease of use and joy of use (Davis, 1989). The concept of immediate interactive behaviour "[...] entails all adaptive activities of agents that routinely and dynamically use their embodied and environmentally embedded nature to support and augment cognitive processes." (Neth et al. 2007, 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 3 seconds), interaction-intensive and without cognitive effort (Neth et al., 2007). There is no deliberate behaviour that can occur on a time scale smaller than that of immediate interactive behaviour (cf. Newell, 1990). The application of simple interaction routines on the one hand alters the environment the agents are acting in and they alter the state of the operators' cognitive system on the other hand (Neth et al., 2007). Its application impacts subjects' motivation due to the experience of their ability to make progress in their interaction. Furthermore, people have feelings of competence based on the successful application of their knowledge (Drewitz & Brandenburg, 2010). If the skill acquisition is facilitated due to the appearance of IIB, operating knowledge (i.e. rule based knowledge) is acquired easily by induction (Brandenburg et al., 2009). Brandenburg et al. (2009) point out that the subsequent execution of simple interaction routines increases the probability that these actions will be linked up with each other and merged into new (procedural) knowledge. In consequence people will experience feelings of ease of use. Examples for such mechanisms of skill acquisition are provided by recent theories of cognition, for instance the production compilation mechanism in ACT-R (Anderson et al. 2000). Closely linked with the ease of use is the joy of use (Davis, 1989). When people extensively show immediate interactive behaviour, ease of induction as well as positive emotional and motivational reactions occur (Drewitz & Brandenburg, 2010; Brandenburg et al., 2013). Again, while proceeding in a task, people become aware of the progress they make. Not getting stuck in an impasse but approaching the interaction goal is accompanied by feelings of success and self-efficacy. As touch interfaces meet most of the characteristics of the structured environment, users should show high levels of immediate interactive behaviour, ease of induction and positive feelings of ease of use and joy of use if being confronted with a touch interface. As pointed out earlier, even the software running on a touch interface can further increase the touch appeal of these artefacts. As in previous works (e. g. Brandenburg et al., 2013) the focus on this paper lies on the software design of touch interfaces.

Research objectives

So far, empirical investigations did not yet deliver clear evidence for the aspect of software affordances (e. g. Brandenburg et al., 2013). Therefore the present study investigates the role of affordances for the emergence of user experience on a multi-touch table. Based on the theoretical input it can be assumed that the presence of affordances does facilitate subjects' performance and leads to more positive user experience compared to their absence. To demonstrate that affordances do affect immediate interactive behaviour and user experience differently than standard signals, we included the presence or absence of arrows as standard signals in the experiment as well (see also Norman, 1999). In contrast to affordances, standard signals are conveyed culturally and their symbolic meanings have to be learned explicitly. Artificial visual indicators are often described as signs or symbols (Petocz et al., 2008). Following Petocz et al. (2008), signs are arbitrary cues that convey a pre-defined message. Thus, signs and symbols are not affordances (Norman, 1999). "They are examples of the use of a shared and visible conceptual model, appropriate feedback, and shared, cultural conventions." (Norman, 1999, p. 41). Arrows are some kind of symbols, defined as a line with one end marked, inducing an asymmetry (cf. Kurata et al., 2005). Arrows have a diversity of semantic roles, e.g. moving direction, physical change, labelling, focusing attention, which have to be learned and distinguished in a given situation (Kurata et al., 2005). Since arrows are a somewhat well learned signal, their presence should increase immediate interactive behaviour and thus elicit a more positive user experience 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.

Method

Subjects and material

A total of $N = 48$ multi-touch table novices (age: $M = 25.9$, $SD = 4.5$, 17 female/31 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.1). These three objects had to be manipulated using different gestures. The subjects' task was to execute the right gestures for rotating, scaling and cutting a blue square (see Fig.2). 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. Additionally, participants were asked to fill in the NASA-TLX (Hart & Staveland, 1989) to assess their subjective experience.

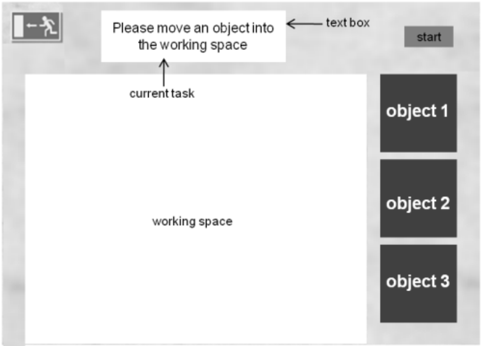

Figure 1. Experimental environment presented on the multi-touch table

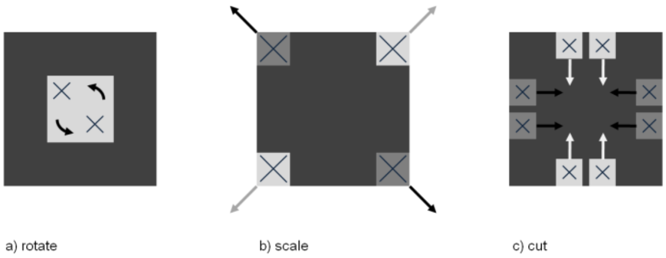

Figure 2. Visualization of the three gestures. In the experiment, all subjects did not see the (light) touch areas. The arrows were presented to the subjects in the corresponding group, only. Crosses are shown for visualization purposes.

Procedure and experimental design

All subjects were randomly assigned to one of the four experimental groups. First, 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. 2a-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. The entire experiment took about 30 minutes.

Two independent variables were manipulated, both as between-subjects variables: affordances that we defined as object movements indicating the gesture specific direction of finger movements and signals that were set out as arrows showing the gesture specific direction of finger movements. Furthermore the three manipulations (rotate, scale, cut) as well as the three trials were included as within-subjects factors. Dependent variables were defined as: *time to first click* that was assessed from the pressing of the start button to the initial manipulation of the object in the working space (it served as one measure of immediate interactive behaviour, see also Drewitz & Brandenburg, 2010), *total task time* that was measured from pressing the start button to the end of task, i.e. the time to correct task accomplishment. It assessed the degree of ease of induction. *Immediate interactive behaviour* was defined as a (reaction) time to the first click that was faster than three seconds. Hence the time to first click was transformed in a dichotomous variable with the categories *immediate interactive behaviour* (time to first click < 3 sec) and *no immediate interactive behaviour* (time to first click ≥ 3 sec) for each of the nine trials. The trials with people showing immediate interactive behaviour have been summed up to get an overall score.

Results

A 2 (Affordances, (aff)) x 2 (Signals (sig)) Analysis of Variance (ANOVA) was calculated for the time to first click, the total task time, immediate interactive behaviour and subjective measures (NASA-TLX). A reparameterized model (Fox, 2008) has been built and contrasts for each hypothesis have been *t*-tested in form of parametric functions ($\Psi{*}c'$). In addition, effect sizes (Cohen's *d*) are reported for each test following Cohen's (1988) interpretation (small effect $d \geq 0.3$; medium effect $d \geq 0.5$; large effect $d \geq 0.8$).

Overall mean time to first click showed a significant, medium effect as to affordances ($t(44) = -2.059$, $p = 0.023$, $d = -0.651$) but neither significant effect as to signals nor as to the interaction of both factors (see Fig.3a). The influence of affordance was not significantly larger than the signal influence, although a small effect could be found ($t(44) = 1.003$, $p = 0.161$, $d = 0.317$) showing that the impact of affordances (natural indicators) on the time to first click is larger than the impact of signals (artificial indicators). Large immediate *learning effects* (see Fig. 3b) were obtained over all gestures ($t(44)= -3.48$, $p = 0.001$, $d = -1.1$). These learning effects did not differ between the conditions of affordances or signals or the interaction of both. No significant learning effect ($d \geq 0.3$) occurred from trial 2 to trial 3.

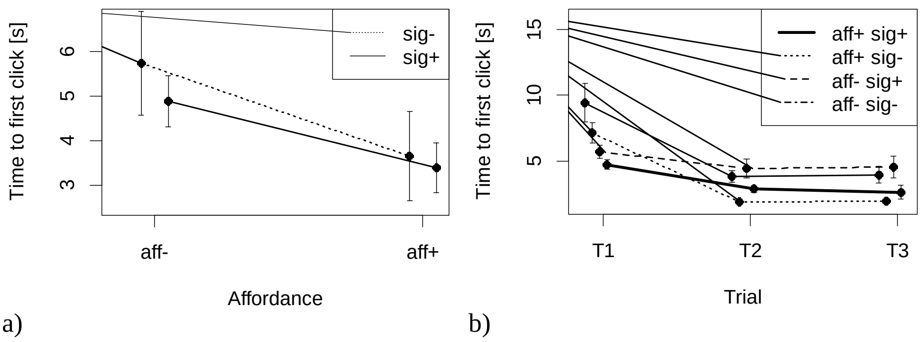

Figure 3. The Effect of a) affodances and signals on TFC and b) learning on TFC

With respect to the total task time (time needed to manipulate a square) large *learning effect* was observed from trial 1 to trial 2 over all groups ($t(44)= -4.157$, $p < 0.001$, $d = -1.314$). The learning effect from trial 2 to trial 3 was significant but of smaller effect size ($t(44)= -1.868$, $p = 0.034$, $d = -0.591$). Analysis revealed a tendency for immediate interactive behaviour occurring more often in the group with affordances (Fig. 4) than in the group without affordances ($t(44) = 1.568$, $p = 0.062$, $d = 0.496$). For signal conditions, the interaction of signals and affordances as well as for the comparison of signals and affordances, neither significant differences nor notable effects were found.

For the subjective data (NASA-TLX) no significant main effects were found, neither for affordance nor signal. However, large effects of the repeated measures factor *time* were obtained for all scales of the NASA-TLX and the overall score. *F*-values were larger than $F = 5.49$, *p*-values smaller than $p = 0.01$ for all scales and effect sizes larger than eta = 0.35. Bonferroni corrected post-hoc tests showed that for almost all scales subjective strain decreased from first to second trial (*p*-values were smaller than $p = 0.01$) and from first to third trial (*p*-values were smaller than $p = 0.01$). Only for cognitive and temporal strain, subjects indicated no change in strain between first and third measurement. However, no scales differed significantly between second and third point in time (*p*-values were larger than $p = 0.20$).

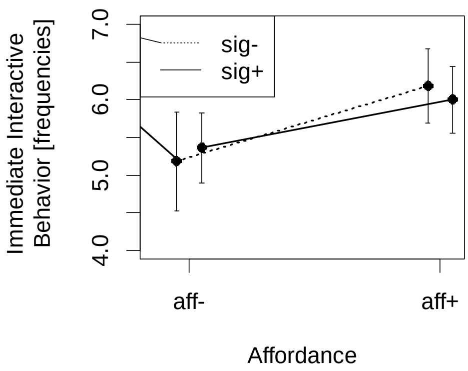

Figure 4. The effect of affordances (aff) and signals (sig) on IIB

Post-hoc power analysis

Post-hoc power analysis should estimate the minimum effect size of tests used in prior analyses of experimental data. Power analysis was calculated for a sample of $N = 48$, $\alpha = 0.05$, $\beta = 0.2$, and one-sided t-tests in the parameterized *2 x 2* ANOVA model. For a power of $1-\beta = 0.8$ effects of $|d| \geq 0.73$ should be found significant. Given the obtained power, it was only likely to detect large effects. Hence, small to medium effects might have been missed in the present study.

Discussion

The present work claims that the appeal of touch interfaces dates back to the way they structure the interaction environment. A multi-touch environment was set up testing the effects of one aspect of the structured environment on subjects’ behaviour and experience. Therefore the effects of two forms of support (i.e. signals and affordances) on users' performance and experience were tested based on the model of user experience framework (Drewitz & Brandenburg, 2010). First, it was hypothesized, that the presence of affordances facilitates the users' performance and experience. Overall, empirical data revealed partial support for this hypothesis. More specifically, subjects initiated an interaction more quickly (i.e. time to first click was lower) if affordances were present. In addition, affordances fostered the occurrence of immediate interactive behaviour. The results are partially in line with previous findings (e.g. Brandenburg et al., 2013) and theoretical considerations (Scarantino, 2003; McGenere & Ho, 2000). For example Brandenburg et al. (2013) showed that affordances did foster the subjects' initial reaction to the artefact and the task completion times. However, here the effect of affordances depended on the presence of signals (Brandenburg et al., 2013). In the current study, affordances clearly outperformed signals regarding the time to first click and immediate interactive behaviour. Theoretical considerations about the inner workings of affordances deliver additional support for the presented results. Following Gibson (1979) and McGenere and Ho (2000), direct interaction fosters direct perception. In turn, direct perception leads to the fast execution of actions based on perceived affordances (see also Albrechtsen et al., 2001; Costall, 1984; Scarantino, 2003). Nevertheless, subjective strain ratings did not support the interpretation that users benefit from affordances in multi-touch interaction. Further investigations should use other methods to assess user experience in these contexts, since NASA-TLX is no user experience measure in the proper sense.

In addition to the hypothesized effects, large learning effects were obtained. Interestingly, participants mostly learned within the first trial. After having performed the gestures once, they were significantly faster in the second trial. After that no further significant learning occurred. This result is in line with previous work of Drewitz and Brandenburg (2010) and Brandenburg et al. (2013) who obtained similar learning curves for time to first click. However, this investigation also revealed some shortcomings. With respect to performance data, large error variances occurred which might have hindered smaller effects to become significant. One reason for this methodical issue is assumed to be due to missing information of location for the index fingers. In other words, if subjects did not know where to put the fingers, they were likely to search for the points of location at the beginning of the gesture execution process. Thus, this search operation might influence empirical as well as subjective data. Regarding subjective data, the present experiment focused on ease of use. Therefore, further studies should focus on the assessment of positive user experience as well. Hence emotions play an important role in user experience processes and influence subjective experience in touch interaction.

References

Albrechtsen, H., Andersen, H.H.K., Bødker, S., & Pejtersen, A.M. (2001). *Affordances in activity theory and cognitive systems engineering* (Report Risø-R-128). Roskilde, Denmark: Risø National Laboratory.

Anderson, J.R. (2000). *Kognitive Psychologie.* Heidelberg: Spektrum Verlag.

Backhaus, N., & Brandenburg, S. (2013). Wie viel ist zu viel? Empfehlungen für die Anzahl von Bedienelementen auf kleinen Displays. In E. Brandenburg, and H. Smiezek (Eds.), *Beiträge zur 10. Berliner Werkstatt Mensch-Maschine-Systeme* (pp.181–186). Düsseldorf: VDI-Verlag.

Brandenburg, S., Drewitz U., Thüring, M., Minge, M., & Brune, T. (2009). Touch me if you can - Immediate Interactive Behavior als Bedienkonzept für Multimediageräte. In A. Liechtenstein, C. Stößel, and C. Clemens (Eds.), *Der Mensch im Mittelpunkt technischer Systeme: 8. Berliner Werkstatt Mensch-Maschine-Systeme* (pp. 248–252). Düsseldorf: VDI Verlag.

Brandenburg, S., Vogel, M., & Drewitz, U. (2013). User experience starts at the keystroke level: The Model of User Experience (MUX). In A. Marcus (Ed.), *DUXU/HCII 2013, Part I, LNCS 8012* (pp. 449–458). Berlin, Heidelberg: Springer.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.

Costall, A.P. (1984). Are there theories of perception necessary? A review of Gibsons' the ecological approach to visual perception. *Journal of the experimental analysis of behavior, 41*, 109–115.

Davis, E.D. (1989). Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *Management Information Systems Quarterly, 13*, 319–340.

Drewitz, U., & Brandenburg, S. (2010). From design to experience: Towards a process model of user experience. In J.C. Lin, D.M. Lin, and H. Chen (Eds.), *Ergonomics for all: Celebrating Ppcoe's 20 years of excellence: Selected papers of the Pan-Pacific Conference on Ergonomics* (pp. 1-6). Oxford: CRC Press.

Fox, J. (2008). *Applied regression analysis and generalized linear models* (2nd edition). Los Angeles, CA: Sage.

Gibson, E.J., (2000). Where is the Information for Affordances? *Ecological Psychology, 12*, 53–56.

Gibson, J. (1979). *The Ecological Approach to Visual Perception.* Boston, MA: Houghton Mifflin.

Greeno, J.G. (1994). Gibson's Affordances. *Psychological Review, 101*, 336–342.

Hart, S.G., & Staveland, L.E. (1988). Development of NASA-TLX (Task Load Index): Results of Empirical and Theoretical Research. In P. Hancock, and N. Meshkati (Eds.), *Human Mental Workload* (pp. 139–183). Amsterdam: Elsevier.

Kurata, Y., & Egenhofer, M. (2005). Semantics of Simple Arrow Diagrams. In T. Barkowsky, C. Freksa, M. Hegarty, and R. Lowe (Eds.), *AAAI Spring Symposium on Reasoning with Mental and External Diagram: Computational Modeling and Spatial Assistance* (pp. 101–104). Pala Alto, CA: AAAI Press

McGenere, J., & Ho, W. (2000). Affordances: Clarifying and evolving a concept. In Canadian Human-Computer Communications Society (Ed.) *Proceedings of Graphics Interface 2000* (pp. 179–186). New York, NY: Lawrence Erlbaum Associates.

Neth, H., Carlson, R.A., Gray, W.D., Kirlik, A., Kirsh, D., & Payne, S.J. (2007). Immediate Interactive Behavior: How Embodied and Embedded Cognition Uses and Changes the World to Achieve its Goals. In D.S. McNamara, and J.G. Trafton (Eds.), *Proceedings of the 29th Annual Conference of the Cognitive Science Society* (pp. 33–34). New York, NY: Lawrence Erlbaum Associates.

Newell, S. (1990). *Unified theories of cognition.* Cambridge, MA: Harvard University Press.

Norman, D.A. (1999). Affordance, conventions, and design. *interactions, 6*, 38–43.

Norman, D.A. (1988). *The Psychology of Everyday Things.* New York, NY: Basic Books.

Petocz, A., Keller, P.E., & Stevens, C.J. (2008). Auditory warnings, signal-referent relations, and natural indicators: Re-thinking theory and application. *Journal of experimental psychology: Applied*, *14*, 165–178.

Scarantino, A. (2003). Affordances explained. *Philosophy of science*, *70*, 949–961.

Vogel, M., Brandenburg, S., & Drewitz, U. (2011). Zur Gestaltung grafischer Benutzerschnittstellen: Einflussfaktoren für das Nutzererleben. In M. Eibl (Ed.), *Mensch & Computer 2011: überMEDIEN|ÜBERmorgen* (pp. 111–120). München: Oldenburg.