Intuition comes with experience

Stefan Brandenburg & Katharina Sachse
Cognitive Psychology and Ergonomics
Technische Universität Berlin
Germany

Abstract

Intuitive interaction utilizes stored experiential knowledge (Blackler et al., 2007a). Several theorists focus on the impact of prior knowledge on intuitive interaction (e.g. Hurtienne & Israel, 2007; Baylor, 2001). However, most empirical investigations look at experiential knowledge that was gained through past experience of some product features under investigation (e.g. Blackler et al., 2010). Hence these experiments do not assure that subjects in the non-experiential group cannot build upon some prior knowledge that was not manipulated in the experiment. In the present empirical investigation this paradigm was extended. Now three groups were tested on a simple multi-touch interface: adult participants with and without prior experience and children as absolutely naive users. Results show that children are generally slower in performance compared to adults. Hence, in line with other research (e.g. Blackler et al., 2010) it can be concluded that prior experience alters intuitive behaviour. In contrast to these studies we claim that there might be different types of prior knowledge, maybe even different types of intuition (see also Baylor, 2001).

Background

The concept of intuition has become very popular in the last decades of human computer interaction research (e.g. Baylor, 2001; Blackler & Hurtienne, 2007; Kindsmüller & Mahlke, 2007). However it still seems to be not well understood (e.g. Hurtienne et al., 2006). Theorists put large effort in their definitions of terms like intuition and intuitive interaction (i.e. Mohs et al., 2006; Baylor, 1997, 2001). One result of these numerous approaches is that one can find many concurrend definitions of inution and intuitive use in recent literature.

Surely one of the shortest definitions of intuition comes from Koestler (1964). He “[...] characterizes [Intuition] as the sudden emergence of a new insight.” (cited in Baylor, 2001, p. 237).

More in general, Bruner (1963) “[...] portrays [Intuition] as the intellectual technique of arriving at plausible but tentative formulations without going through the analytical steps by which such formulations would be found to be valid or invalid.” (cited in Baylor, 2001, p. 237). Jung (1921) “[...] describes [Intuition] as the psychological function that explores the unknown and senses possibilities and indications which may not be readily apparent.” (cited in Baylor, 2001, p. 237). In

In D. de Waard, K. Brookhuis, F. Dehais, C. Weikert, S. Röttger, D. Manzey, S. Biede, F. Reuzeau, and P. Terrier (Eds.) (2012). Human Factors: a view from an integrative perspective. Proceedings HFES Europe Chapter Conference Toulouse. ISBN 978-0-945289-44-9. Available from http://hfes-europe.org

contrast to these very broad definitions, Haidt (2001) puts the time scale of intuition into focus by stating that "[...] Intuition can be defined as the sudden appearance in consciousness of a [...] judgement, including an affective valence (good-bad, like-dislike), without any conscious awareness of having gone through steps of searching, weighting evidence, or inferring a conclusion [...]." (cited from Plessner, 2006, p.110). In coherence with Haidt (2001), Baylor (1997) also mentions the short time scale of intuitive processes by defining that, "First, intuition has an element of immediacy. [...] Second, intuition senses relationships. Intuitive processes draw links and highlight patterns, formulating connections between objects or ideas. Third, intuition is a type of reasoning. […] Intuition results from a reasoning process that lacks metacognitive control. Reasoning in intuition proceeds automatically, immediately interpreting the present relationship. In summary, intuition acts in the immediate future, senses relationships, and functions through reasoning without conscious intent." (p. 3).

Finally, Blackler, Popovic and Mahar (2007) transfer the definition of Intuition into the area of man-machine interaction. "Intuition is a type of cognitive processing that is often non-conscious and utilises stored experiential knowledge. Intuitive interaction involves the use of knowledge gained from other products and/or experiences." (Blackler et al., 2007, p.4). Furthermore they even define intuitive interaction for this area. "Intuitive use of products involves utilising knowledge gained through other experience(s). Therefore, products that people use intuitively are those with features they have encountered before. Intuitive interaction is fast and generally non-conscious, so people may be unable to explain how they made decisions during intuitive interaction" (Blackler, Popovic & Mahar, 2007 p. 5).

Despite the variety of constructs that are related to intuition and intuitive interaction in these definitions, some key elements are frequently mentioned. First of all, some type of insight/formulation/new possibility seems to be the result of an intuitive process. Second, people come to these insights without conscious reasoning. Third, intuitive processes are fast and fourth, some type of prior knowledge forms the basis of the intuitive process. Especially the usage of prior knowledge seems to be most important for intuitive processes. However, none of these definitions define which type of prior knowledge is necessary to facilitate intuitive interaction. Hence the present paper experimentally varies this factor to shed some light on this issue. Since it was aimed to assess intuitive behaviour with respect to a new technical artifact, we grouped subjects regarding their prior knowledge with a special multi-touch interface (i.e. a multi-touch table). One group consisted of pre-school children who were assumed to have no prior knowledge of multi-touch devices at all. A second group consisted of adults, who had no prior experience with the multi-touch interface used in the study. The third group, also adults, had the chance to interact with the special multi-touch interface in advance of the study, so they had specific operating knowledge.

In literature at least two approaches focus on the role of prior knowledge for intuitive behaviour, the *continuum of prior knowledge* (Hurtienne & Israel, 2007; Mohs et al., 2006; Naumann et al., 2007) and *im-/mature intuition* (Baylor, 1997). Hurtienne and Israel (2007) assume that intuitive interactive behaviour is based on pre-existing knowledge that may stem from different sources. These knowledge sources build up a continuum (see figure 1). The continuum of knowledge in intuitive interaction starts at the level of reflexes or instinctive behaviour (*innate knowledge*). The second level is called *sensorimotor*. According to Hurtienne and Israel (2007) “It consists of general knowledge, which is acquired very early in childhood and is from then on used continuously through interaction with the world” (p. 128). The third level is called *culture*. It contains “knowledge specific to the culture an individual lives in” (p. 128). At the top of the continuum is expert knowledge which is specialist knowledge acquired in ones profession or in hobbies. The sensorimotor, culture and expertise level of knowledge also contain knowledge about tools. While the tool related knowledge in the sensorimotor level is rather primitive (e.g. using sticks to extend ones reach), the tool related knowledge on the culture level is about using common tools like cell phones. For the highest knowledge level there is knowledge about using specific tools acquired by performing ones profession or hobbies (e.g. using MS Power Point). The more often knowledge at each level was encoded and retrieved in the past the less awareness is needed to apply this knowledge.

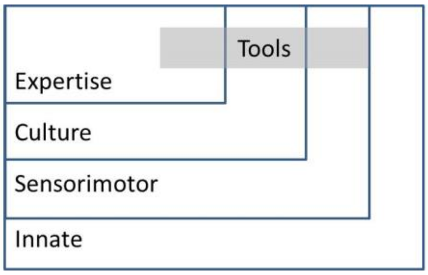

Figure 1: Continuum of knowledge for intuitive use (Hurtienne & Israel, 2007)

What does this mean for intuitive interaction? Hurtienne and Israel (2007) argue that interaction is intuitive as long as prior knowledge is unconsciously applied by users. Following their line of argumentation, children would only posess knowledge of the innate or sensimotor level of expertise regarding a new technical artifact like a multi-touch interface. Therefore they cannot use operating knowledge regarding this kind of tools. Hence children should not be able to intuitively use the multi-touch interface, which should result in slow interaction. Adults without experience with a specific device (i.e. a multi-touch interface) have used touch interfaces at least. Therefore they might have knowledge as high as the culture level and can rely on their operating knowledge regarding touch interfaces. Instead, subjects having a phase of prior exploration with a special artifact (i.e. a multi-touch interface) gained specific knowledge on the level of tools additionally to their general knowledge of touch intercfaces. These participants have prior knowledge on all levels of the continuum of prior knowledge. Hence the approach of Hurtienne and Israel (2007) suggests, that subjects with more specific knowledge regarding a special tool (i.e. a multi-touch interface) should perform faster than people without that knowledge.

The second approach to the role of prior knowledge for intuitive behaviour lies in the distinction of immature and mature intuition from Baylor (2001). Based on her analysis of the three components of intuition (immediacy, reasoning and relationships) Baylor (2001) concludes that the availability of intuition is about the same for novices and experts. However, the basis for their intuition is different. “Immature intuition is accessed when a person has less-developed knowledge structures and acts as a novice. Once a person attains more expert knowledge structures, s/he develops the ability to figuratively ‘‘see’’ diff erent relationships and thus demonstrate mature intuition.” (Baylor, 2001, p. 240). However, the availability of intuition follows a U-shaped function with the development of expertise. Relating these assumptions to an interaction with a multi-touch interface, children would be placed on the side of novices, participants with prior experience on the side of experts and participants without prior knowledge inbetween both extremes. Hence, intuition should be highly available for both, children and participants with prior knowledge. Based on the assumption that intuitive behaviour is uncontious and fast, it is to be expected that children and experts need about the same time for interacting with a new type of interface, and both are faster than subjects without special experience.

Summing up, the present study investigates prior knowledge regarding the operation of a multi-touch interface. Therefore a group of children is tested against adults without specific operating knowledge and adults with prior experience with the artifact. Based on literature two hypothesis are put up:

1) If subjects can be assigned to different stages of the continuum of prior knowledge (Hurtienne & Israel, 2007), subjects on the sensorimotor stage (children) should be slower than subjects at the culture stage (adults without prior experience). Additionally, subjects having knowledge about the tool (adults with prior experience) should be faster than subjects without knowledge about the tool (adults without prior experience).

   In contrast:

2) In case of the existence of im-/mature intuition (Baylor, 2001) novices (i.e. children) and experts (i.e. adults with prior experience) should be faster than intermediates (i.e. adults without prior experience).

Method

Material

The experimental environment was a multi-touch sensitive interface on a selfmade multi-touch table (about 80 cm x 105 cm). The interface shown to the subjects consisted of a workspace, a text box presenting the current task, a start button and three objects on the right hand side (see fig. 2).

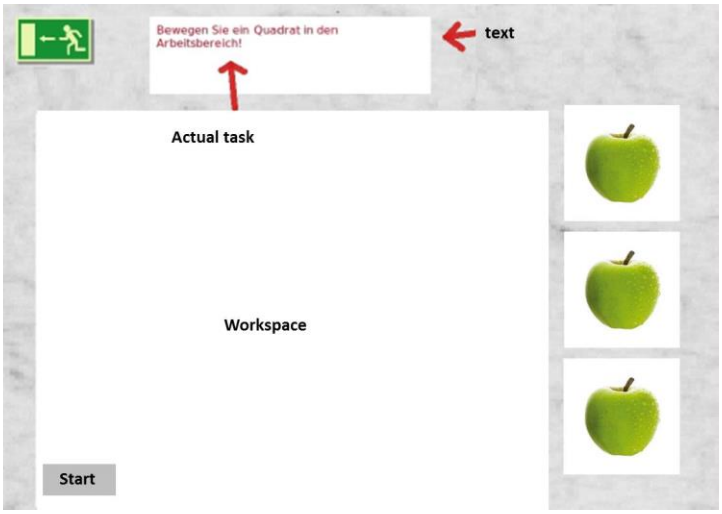

Figure 2. The multi-touch interface.

Subjects' task was to execute three different manipulations with the objects (i.e. rotate, cut, scale) by performing the right gesture. Figure 3 shows these gestures including touch-points (i.e. crosses in squares) and direction of possible gesture execution (i.e. arrows).

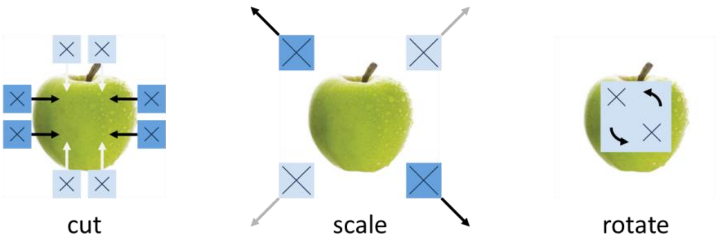

Figure 3. The three gestures including touch-points (crosses in squares) and indicators for possible direction of gesture execution (arrows).

Participants

To test for the hypothesis [that different levels of experience result in different types of intuitive use] we conducted tests with three different groups of users. The first group consisted of eleven 5 to 6 year old pre-school children (five male, six female). For this group it can be assumed that they have nearly no experience in using multi-touch devices (only one child indicated that she was used to handle a touch screen). The two other groups consisted of 23 adults (11 male, 12 female, range of age from 23 to 27, M = 24.5, SD = 1.51) that were randomly assigned to one of two conditions. In the *with prior experience* condition participants were allowed to explore the multi-touch interface before they solved the tasks. Therefore they were allowed to interact with a picture and movie manipulation programme for about two minutes before the experiment. In the *without prior experience* condition the experimental tasks had to be solved without the chance to explore the device in advance.

Procedure

Before the test trials started, participants were instructed that they have to manipulate each of the three objects shown on the interface. The order of the tasks was selected at random for each interaction. To start a trial subjects had to drag one of the objects into the middle of the screen. Then, they were requested to execute the particular manipulation with the object (i.e. cut, rotate, or scale). To start with this manipulation, participants had to press the start-button. In doing so, time assessment started. Then they performed a gesture to manipulate the object. When the task was successfully solved, the object disappeared. To proceed with the next task, a new object had to be dragged into the middle of the screen. When all three types of manipulations were executed, the trials started again. So each participant performed each gesture twice.

Doing tests with children requires some special considerations. First, pre-school children are usually not able to read, so it is necessary to instruct them verbally. The instructions have to be presented in a standardized manner, since small changes in wording might have a substantial impact on the interaction (see also McKnight & Fitton, 2010). A female instructor read out the tasks to all subjects and invited them to use their index fingers to exercise the tasks. She provided no information how to perform the gestures. Second, the attention span of young children is rather short. To motivate them to finish the tests the tasks were introduced as a game where the children have to solve small puzzles. We did not use this cover story for the adult participants.

Results

As objective measures we assessed two different times, Time to First Click (TFC) and Total Task Time (TTT). Whereas TFC captures the delay from pressing the start button to the start of gesture execution, TTT assesses the over-all performance from pressing the start button to the dissapearance of the object (successful completion of the task). Hence TFC indicates extend of immediate behaviour (see also Newell, 1990; Neth et al., 2007) and TTT over-all performance (see also Brandenburg et al., 2009; Drewitz & Brandenburg, 2010). For data analysis a three-way MANOVA was computed with time (t1 & t2), gesture (cut, rotate & scale) and group (children, adults with experience and adults without experience) as within-subjects factors. Dependents were Total Task Time (TTT) and Time to First Click (TFC). Additionally, post-hoc tests (e.g. Scheffé test) were computed if applicable. Finally the effect size eta with $eta < 0.08$ being small, $0.08 < eta < 0.14$ regarded as medium and $eta > 0.14$ considered as large are reported (see also Cohen, 1988).

First of all a significant effect of time was obtained for both measures, TTT ($F(1,31) = 44.19$, $p < 0.001$, $eta = 0.58$) and TFC ($F(1,31) = 18.75$, $p < 0.001$, $eta = 0.38$). Hence subjects became faster in their task performance (TTT) and their initial reaction (TFC) over time. However, this effect was not the same for all three groups. A significant interaction of time and group occured for both, TTT ($F(2,31) = 4.72$, p

= 0.01, eta = 0.23) and TFC (F(2,31) = 3.71, p = 0.03, eta = 0.19). Figure 4a/b visualizes these results. Most importantly, at time point one (subjects first experimental encounter with the interface) post-hoc Scheffé tests revealed, that children differed significantly from adults with (TTT: p = 0.001; TFC: p < 0.001) and without experience (TTT: p = 0.001; TFC: p = 0.01).

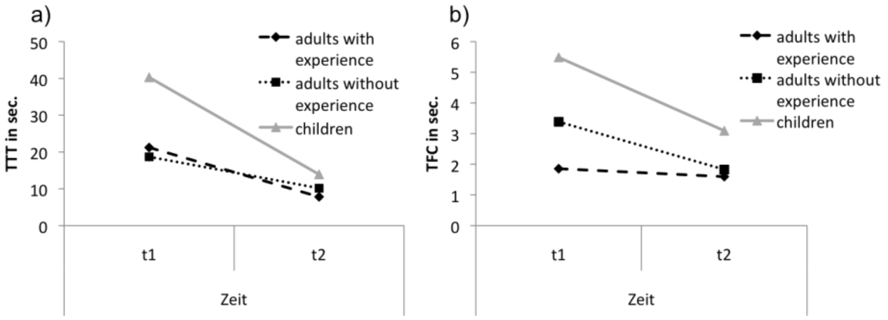

Figure 4. interaction of group and children regarding a) their total task performance and their initial reaction time.

Since the result of TFC at time point one is important to the authors line of argumentation and statistical power was quite low (1-ß = 0.61), a second analysis of TFC at time 1 using the Bayes Factor was performed (e.g. Dines, 2011). The Bayes factor (BF) „[...] distinguishes data supporting the null from data uninformative about whether the null or your theory was supported.” (Dines, 2011, p. 278). Jeffreys (1961) suggests Bayes factors above 3 or below one third are ‘‘substantial,’’ though the evidence is continuous and there are no thresholds as such in Bayesian theory.” (Dienes, 2011, p. 277f). For the current question it was tested, whether the differences in TFC between group means at time point one (fig. 3b) are evidence for a substantial effect of prior knowledge[1]. In other words, a BF over 3 means that two groups are different from each other. A BF between 3 and 0.33 states that the empirical evidence is not sensitive enough to decide wether two groups differ. Finally a BF lower than 0.33 means that two groups are not different from eachother. The Bayes Factor analysis followed standard procedures as described in Dines (2011). Results revealed, that the mean difference of children and adults without experience ($M_{\text{children-adults without experience}}$ = 2.1 sec.) corresponds with a Bayes Factor of BF = 3.02. The mean difference of children and adults with experience ($M_{\text{children-adults with experience}}$ = 3.36) lead to a Bayes Factor of BF = 725.98. Finally, the mean difference of adults with and without experience was $M_{\text{adults with – adults without experience}}$ = 1.53 and corresponded to a Bayes Factor of BF = 13.64.

Coming to a conclusion: The data support hypothesis 1, i.e. the continuum model proposed by Hurtienne and Israel (2007). Subjects on the sensorimotor stage (children) are slower than subjects at the culture stage without knowledge about the

---

[1] A uniform distribution was applied. The largest mean of the children-subgroup (5.48) was set as upper limit. Zero was set as lower limit.

tool (adults without prior experience), who are, in turn, slower than subjects with knowledge about the tool (adults with prior experience). Hypothesis 2 has to be rejected.

In addition to the effects regarding the hypothesis, the MANOVA revealed significant differences regarding subjects' task performance (TTT) performing the three gestures, $F(2,62) = 26.34$, $p < 0.001$, eta = 0.49. Hence, post-hoc tests revealed that subjects were significantly slower in executing the gesture cut compared to scale ($p = 0.001$) and rotate ($p < 0.001$). Scale was also slower than rotate ($p = 0.006$). Finally two more meaningful interactions with respect to the total task performance (TTT) were obtained. One shows that adults were faster in the execution of the gestures cut and scale but as fast as children for the gesture rotate, $F(4,62) = 2.27$, $p = 0.06$, eta = 0.12. The second interaction deals with the fact that subjects did not equally improve their total task time over gestures and time, $F(2,62) = 6.50$, $p = 0.003$, eta = 0.17. Here the performance of the gestures cut and scale was improved from trial one to trial two. No improvement was seen for rotate which execution was already fastest at time point one (about 10 sec.).

Discussion

The aim of the present paper was to examine the effect of prior knowledge on measures of intuitive behaviour in a laboratory setting. Therefore an experiment was conducted in which three groups of participants executed three different gestures on a multi-touch interface at two different points in time. First of all, data showed that subjects became faster over time with respect to the time needed for gesture execution (TTT) and their initial reaction time (TFC). Additionally, subjects did not learn all gestures equally well. Both effects are in line with previous research (e. g. Zinn & Brandenburg, 2011).

Second, and more important, children differred from adults with and without prior experience regarding their initial reaction time at their first encounter with the interface. Surely, Scheffé post-hoc tests only indicated significant differences between children and both adult groups. Moreover, the Bayes Factor calculation revealed strong support for differences between all three groups. Hence one can conclude that the type of prior knowledge matters for intuitive behaviour. Again, children did not have any prior knowledge, neither with multi-touch interfaces, nor with mobile or other touch-devices. Adults in the without prior knowledge group did not have any specific multi-touch interface knowledge either. However, they mainly reported at least ocassional use of Smartphones or other devices with multi-touch interfaces. Hence, only adults in the with prior knowledge group had the opportunity to gain some experience with the multi-touch interface through their two-minute free exploration of a picture and movie manipulation software. So how can these differences in prior knowledge account for group differences in immediate interactive behaviour (TFC)? As opposed to Baylor (2001), Hurtienne and Israels (2007) continuum-model accounts for the observed initial reaction time differences. As proposed by the continuum of prior knowledge, the degree of experience varied with its specifity for the experimental task. The more specific the prior knowledge was, the faster the participants. However the continuum of prior knowledge as described from Hurtienne and Israel (2007) does not explicitly predict time differences between children and adults with and without prior experience. They rather state that subjects have more sources of prior knowledge the higher they are in the continuum. This leaves space for at least one more explanation of the effect, transfer of existing knowledge (Raskin, 1994). His explanation might be the most promising approach to the present time differences. Raskin (1994) states: “I suggest that we replace the word “intuitive” with the word “familiar” (or sometimes “old hat”) in informal HCI discourse. HCI professionals might prefer another phrase: Intuitive = uses readily transferred, existing skills.” (p. 20). Following that argumentation, differences in intuitive interaction might occur based on the level of familiarity with the artifact. Hence children were the least familiar with multi-touch interfaces. Adults without experience at least stated experience with other multi-touch interfaces. Finally, subjects that experienced the multi-touch interface in a phase of free exploration had the highest level of familiarity. Hence it should have been easier for subjects to transfer their existing knowledge the more this knowledge corresponded to the experimental task. This proposal frames the observed time differences as analogous problem solving (cf. Anderson, 1996). However, as with the other two approaches before, Raskins definition has at least one shortcoming as well. In the present experiment, adults that were able to explore the multi-touch interface had a two-minute time slot for this task, only. Raskin (1994) claims “existing skills” to be the cause for the behaviour which is usually named intuitive. One can doubt that adults in the *with prior experience* group gathered special skills in their two-minute exploration.

To sum up, the present investigation tested whether different types of prior knowledge influence intuitive behaviour. To test this hypothesis three groups of participants manipulated simple objects on a multi-touch interface. Data analysis showed, that the present study replicates known effects with respect to learning and the differential effect of gestures (e.g. Zinn & Brandenburg, 2011). Additionally, we found that different levels of prior knowledge lead to divergent intuitive behaviour, reaction times respectively. Three approaches were discussed to explain the experimental results. However, all of them were insufficient to completely account for the empirical data. Regarding these theoretical approaches it might be that children as well as intermediates and experts show intuitive behaviour. Childrens behaviour might be due to their immature intuition. Intermediates might use their prior knowledge as described by Hurtienne and Israel (2007) and experts might have transferred their specific prior knowledge from one multi-touch application to another as proposed by Raskin (1994). Future research will have to show.

References

Anderson, J.R. (1996). *Kognitive Psychologie*. Spektrum Akademischer Verlag. Heidelberg.

Baylor, A.L. (1997). A three-component conception of intuition: Immediacy, sensing relationships, and reason. *New Ideas in Psychology*, 15, 185-194.

Baylor, A.L. (2001). A U-shaped model for the development of intuition by level of expertise. *New Ideas in Psychology*, 237–244.

Blackler, A.L., Popovic, V. & Mahar, D.P. (2007). Empirical investigations into intuitive interaction: a summary. In: Kindsmüller, M.C. & Mahlke, S., *MMI-Interaktiv, 13,* 4 - 24.

Blackler, A.L., Popovic, V. & Mahar, D.P. (2010). Investigating users' intuitive interaction with complex artefacts. *Applied Ergonomics*, *41,* 72-92.

Brandenburg, S., Drewitz, U., Minge, M., Thüring, M. & Brune, T. (2009). Touch Me, If You Can – Immediate Interactive Behaviour als Bedienkonzept für mobile Multimediageräte. In: Lichtenstein, A., Stößel, C. & Clemens, C. (Hrsg.). *Der Mensch im Mittelpunkt technischer Systeme. 8. Berliner Werkstatt Mensch-Maschine-Systeme* (pp. 1-8). Düsseldorf: VDI Verlag.

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

Dienes, Z. (2011). Bayesian versus orthodox statistics: Which side are you on? *Perspectives on Psychological Science*, *6*, 274–290.

Drewitz, U. & Brandenburg, S. (2010). From design to experience: Towards a process model of user experience. In: Lin, J.C., Lin, D.M. & Chen, H. (Hrsg.): *Ergonomics for all: Celebrating PPCOE's 20 years of excellence: Selected papers of the Pan-Pacific Conference on Ergonomics* (pp. 117-122). Boca Raton: CRC Press..

Hurtienne, J., Mohs, C., Meyer, H., A., Kindsmüller, M., C., Israel, J., H. & die IUUI Research Group (2006). Intuitive Use of User Interfaces - Definition und Herausforderungen. *i-com - Zeitschrift für interaktive und kooperative Medien*, *5* (3), 38-41.

Hurtienne, J. & Israel, J.H. (2007). Image Schemas and Their Metaphorical Extensions – *Intuitive Patterns for Tangible Interaction TEI'07*, 15th-17th February, Baton Rouge, LA, USA, 127 – 134.

Kindsmüller M.C. & Mahlke, S. (2007). Editorial: User Experience – Recent approaches to intuitive use and hedonic aspects in human-technology interaction. In: Kindsmüller, M.C. & Mahlke, S., *MMI-Interaktiv* (13), 1 - 4.

McKnight, L. & Fitton, D. (2010). Touch-screen Technology for Children: Giving the Right Instructions and Getting the Right Responses. In: *Proceedings of the 9th International Conference on Interaction Design and Children*. New York: ACM.

Mohs, C., Hurtienne, J., Scholz, D. & Rötting, M. (2006). Intuitivität - definierbar, beeinflussbar, überprüfbar. *In Useware 2006* - VDI Berichte Nr. 1946 (pp. 215-224). Düsseldorf: VDI-Verlag.

Naumann, A., Hurtienne, J., Israel, J.H., Mohs, C., Kindsmüller, M.C., Meyer, H.A. & Husslein, S. (2007). Intuitive Use of User Interfaces: Defining a Vague Concept. In: D. Harris (Ed.). *Engineering Psychology and Cognitive Ergonomics, 13* (pp. 128-136). Heidelberg: Springer.

Neth, H., Carlson, R. A., Gray, W. D., Kirlik, A., Kirsh, D., & Payne, S. J. (2007). Immediate Interactive Behaviour: 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). Nashville, TN: Cognitive Science Society.

Newell, A. (1990). *Unified Theories of Cognition*. Harvard University Press. Cambridge, Massachusetts.

Plessner, H. (2006). Die Klugheit der Intuition und ihre Grenzen. In: Scherzberg, A. *Kluges Entscheiden*. Verlag Mohr Siebeck.
Raskin, J. (1994). Intuitive equals familiar. *Communications of the ACM*. 37:9, September 1994, p. 17.
Zinn, J.M. & Brandenburg, S. (2011). Support of Gesture Learning for MultiTouch Interfaces. In: Schmid,S., Elepfand, M., Adenauer, J. & Lichtenstein, A. (Hrsg.): *Reflexionen und Visionen der Mensch-Maschine Interaktion. Aus der Vergangenheit lernen, Zukunft gestalten 9. Berliner Werkstatt Mensch-Maschine-Systeme* (pp. 134-142). Düsseldorf: VDI Verlag.