Designing for Children
- With focus on 'Play + Learn'

Child and Design Factors interacting in Children's HCI

Helping children focus on the content, not the interface

Shuli Gilutz, Teachers College, Columbia University, New York, USA, sg2108@columbia.edu
John B. Black, Teachers College, Columbia University, New York, USA, black@tc.columbia.edu

Abstract: Children's comprehension of novel computer interfaces was studied in a series of studies with three-to-five year olds. In one study 117 children of a low SES group were presented with four novel interfaces differing in levels of complexity and familiarity. Parental questionnaires were used to assess children's previous technology experience. Comprehension of the interface was measured by children's ability to recognize the actions needed to play the game. Findings revealed a significant three-way interaction between age, technology-experience, and complexity; with age and experience moderating the effect of complexity on children's comprehension and creating three significant interface-comprehension groups. Familiarity had an overall positive main effect. The implications of the importance of designing for low complexity, high familiarity, and the appropriate age and technology-experience level are discussed.

Key words: Usability, Young children, Digital interfaces, Age-appropriate design.

1. Introduction

How do children know what to do on novel digital interfaces – where to click, what to drag, how to scroll? What role do child factors such as child-development and technology-exposure play? What role do the interface design and elements such as complexity and familiarity play? This paper will try to tease these issues apart and answer some of these questions.

While many adults struggle with comprehending and manipulating digital interfaces (Norman, 1999), today's young children are a generation of "clickerati" (Harel, 1997) or "digital natives" (Prensky, 2001) who approach these interfaces with the same matter-of-fact approach to getting dressed, but usually with the excitement—and motivation—of going to an amusement park. However they may not completely understand how to use it, or what the implications are.

Gilutz and Nielsen found that children struggled with many design features on children's websites, and actually succeeded in comprehending adult-oriented design features (Gilutz & Nielsen, 2002). Since then there have been improvements in website's design for children, but the situation is far from standardized in terms of visual language and conventions.

1.2 Child Factors: age & technology-experience

According to User Centered Design, interfaces should be designed according to users' capabilities, needs, and expectations, using usability testing to undercover problems and an iterative design cycle (Norman & Draper, 1986). In the same manner, children's unique characteristics play an important role in creating a successful user experience for them (Brouwer-Janse, et al., 1997; Hanna, 2007; Haugland, 1992).

However, child factors such as age and technology-experience have not been incorporated consistently in children's interface research, so we do not know how they interact with each other, or with other factors such as the design elements themselves. (Glaubke, 2007; Hourcade, 2008).

As people develop from birth to adulthood, many of their cognitive and physical abilities increase over time (Kail, 1991; Miller & Vernon, 1997; Rao, 2006). Children are different than adults in the way they think and learn, and this difference changes over time until adulthood. Maturation plays a role in learning, however it does not guarantee that learning will occur, rather, it limits what children can do (Piaget, Inhelder, & Weaver, 1969).

The variable of age, therefore, encompasses in it many critical developmental differences in children's ability to interact with technology. While there is a lot of variance within an age group, studies have shown significant differences in the way children interact with interfaces even with one year age difference (Druin, 2002; Egloff, 2004).

Another critical variable in children's HCI is that of experience. Research with adults has shown significant differences between experts' and novices' learning (Chase & Simon, 1973; Chi & Glaser, 1985; Kalyuga, Ayres, Chandler, & Sweller, 2003). Similarly, there have been studies that show that children's previous experience with technology significantly affected their learning of new interfaces (Donker & Reitsma, 2004). Children's exposure to technology enhances their ability to learn novel interfaces, however it is unclear to what degree, and how this effect changes over time.

1.3 Design Factors: familiarity & complexity

Two design factors may have a stronger impact on children: familiarity and complexity (Gilutz & Black, 2006). People interact with technology based on their mental models of its system (Norman, 1983). Ideally, an interface design will be consistent with people's natural mental models about computers, the environment, and everyday objects. Interface metaphors can serve as models; they allow designers to take knowledge of familiar objects and events and to use that knowledge to give structure to less well understood concepts using a familiar scheme (Cates & Berkley, 2000; Erickson, 1990).

Lack of complexity of an interface has been shown to be an important factor in adults' ease of use (Tullis, 1998). By adding items to the interface, designers increase the extraneous cognitive load of the user, and risk an overload situation in which the user will not have enough cognitive resources left for comprehending the interface (Sweller, 1994). The less complexity – the less cognitive load – the more resources for learning.

This study aims to look at the relationship between child factors (age, technology-experience) and design factors (complexity and familiarity), and preschoolers' ability to comprehend a novel interface.

2. Method

2.1 Participants

117 children between the ages of three and five (M = 4.2, Mdn = 4.2) were recruited from seven preschools in a low SES area in a large Israeli city (69 boys, 48 girls).

2.2 Materials

Four novel interfaces were designed varying in levels of familiarity and complexity (Table 1). The Paint Pad interface (Table 1 a., b.) represents a standard coloring book, a familiar environment utilizing a metaphor based on a non-computer environment the participants have used before (i.e. painting). The elements on the interface are: a picture for coloring, four basic colors set in a water-color-type palette on the side, and a navigation element below that enables the users to scroll through three possible pictures.

The Monster Maker interface (Table 1, c., d.) is a novel interface, an unfamiliar environment in which participants have no prior knowledge regarding how to play the game. Users can design their own monster by clicking on three elements that: a facial expression, body shape, and legs. They must then click the question mark icon on the right, and the new monster appears.

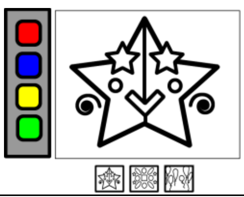
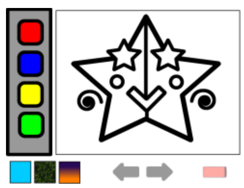
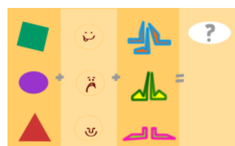
a. familiar simple	b. familiar complex	c. unfamiliar simple	d. unfamiliar complex
			

Table 1. Interfaces used across conditions

Paint Pad and Monster Maker had been designed in two versions so that each reflected two levels of complexity: simple and complex. The two versions differ in the number of actions that are available on the screen for exploring and clicking. The same number of five core actions is needed to play the basic game; however in the complex version there are five additional peripheral actions that add to the richness of the game, but also may distract.

Each participant used a laptop with a Kidz© mouse with a one-click option. The sessions were videotaped using Morae software and a webcam, which captures both the child's face and their actions on the screen simultaneously.

2.3 Design

The experiment used a 2x2x2x3 between-subjects design where the independent variables were: age (younger, older), technology-experience (none, low, high), complexity (simple, complex), and familiarity (familiar, unfamiliar). The dependent variable was comprehension of the interface.

Technology-experience was measured by questionnaires completed by a caregiver of each participant, then scored and using factor analysis creating one principal component of experience that was divided into three levels (none, low, and high experience).

Familiarity was manipulated by using two types of interfaces: Paint Pad and Monster Maker. Complexity was manipulated by the number of actions available on the screen (five or ten).

Comprehension of the interface was measured by participants' ability to recognize the actions needed to play the game. The comprehension score includes an assistance score as a modifier of the final score (1 for no help, 0.75 for one-time help, 0.5 for more-than-once help). Assistance is defined as giving the participants information they have not found by themselves. Assistance was given only as a last resort, when the participant wanted to stop the session. Interface comprehension = assistance*(actions recognized/5).

2.4 Procedure

Each participant and a researcher sat together at a child-height desk in a separate room from the main classroom. Sessions lasted 25 minutes on average. The researcher explained that he or she would be presented with new computer games, and their help is needed figure out how to play the games. The researcher presented the participant with a randomly assigned interface (within age-groups), and asked: "Can you show me how to play this game?". Each participant played the game on their own for up to 5 minutes, and were then prompted to look for advanced features, for example: "Can you find another drawing to color?".

3. Results

The data was analyzed using a 2 x 2 x 2 x 3 factorial ANOVA, with comprehension as the outcome. The model was found statistically significant $F(23,116) = 3.27$, $p < 0.01$, $r2 = 0.447$.

All four independent variables were found significant as well: age $F(1,116) = 14.58$, $p < 0.01$, $r2 = 0.136$, technology experience $F(2,116) = 4.26$, $p = 0.017$, $r2 = 0.084$, complexity $F(1,116) = 6.75$, $p = 0.011$, $r2 = 0.068$, and familiarity $F(1,116) = 8.46$, $p < 0.01$, $r2 = 0.083$. Additionally, one 3-way interaction was found significant: age, technology-experience, and complexity $F(2,116) = 4.56$, $p = 0.013$, $r2 = 0.089$.

Overall, when comparing the means of the 12 conditions, two conditions are statistically significant from the other ten: the younger children with no technology-experience in the complex condition (M=46.08), and the older children with high experience in the simple condition (M=100). The other ten group means are significantly different from these two, but not from each other (range of M=77.71 to M=90.00) (Table 1).

<table>
<tr><th>experience</th><th>complexity</th><th>age</th><th>Mean</th></tr>
<tr><td rowspan="4">none</td><td rowspan="2">simple</td><td>younger</td><td>83.75</td></tr>
<tr><td>older</td><td>79.38</td></tr>
<tr><td rowspan="2">complex</td><td>younger</td><td>*46.08</td></tr>
<tr><td>older</td><td>83.81</td></tr>
<tr><td rowspan="4">low</td><td rowspan="2">simple</td><td>younger</td><td>84.25</td></tr>
<tr><td>older</td><td>90.00</td></tr>
<tr><td rowspan="2">complex</td><td>younger</td><td>69.69</td></tr>
<tr><td>older</td><td>89.38</td></tr>
<tr><td rowspan="4">high</td><td rowspan="2">simple</td><td>younger</td><td>77.71</td></tr>
<tr><td>older</td><td>*100.00</td></tr>
<tr><td rowspan="2">complex</td><td>younger</td><td>80.00</td></tr>
<tr><td>older</td><td>86.52</td></tr>
</table>

Table 1: Mean scores of comprehension of the interfaces in all conditions

4. Discussion

The significant interaction between age, technology-experience, and complexity indicates that the impact of these variables on comprehension of novel interfaces is more intricate than we would have expected. When combined, they created three different groups of users. About 83% of the participants received more or less the same score of 80% comprehension, about 8% of the participant received a low score of 46% comprehension, and about 8% of the participants received a high comprehension score of 100%.

The creation of these three groups implies that (a) it is indeed possible to design for the majority of the group even with differences in these variables, (b) without addressing the needs of the younger and not experienced sub-group they will be significantly left behind and not be able to use the interface, (c) it is possible to achieve a 100% interface-comprehension score that will allow for the children’s mental effort to put in play and learning of content of the digital experience rather than struggle with the interface.

4.1 Designing for the majority of your user group

By relying on developmental theory and usability testing, we can find the appropriate levels of complexity and familiarity for the cognitive abilities for a specific age group. Technology-experience lessens the effects of the design factors, and therefore can assist the younger audience. By user testing with the target audience designers can find out what the comprehension level is and then adjust their design accordingly.

Another solution is to use a layered design that evolves as the child gets more experienced, and/or older (Jackson, Krajcik, & Soloway, 1998; Salomon, Globerson, & Guterman, 1989; Shneiderman, 2003). The initial design would include fewer elements and actions possible, and a more familiar environment in terms of metaphor. The older and/or more experienced the user is the more complex and unfamiliar the design could get.

4.2 Taking into consideration no technology-experience and younger children

The one group that did significantly worse than everybody else was that of the younger children that had no technology experience, that were presented with a complex interface. This group scored 46% comprehension, while all the others scored over 80% comprehension. The younger users have a lower mental effort capacity, and without experience with the medium to help them out, a complex interface is too much for them to process. They therefore fail at comprehension of the interface, and do not even get to experience the content presented for play and learning. This study shows that this situation may be avoided in two ways: manipulating either the interface design or by giving this group some technology experience. Designers can change the interface to a simpler one that would demand less cognitive resources, and significantly change the younger and inexperienced group's comprehension (from 46% to 80%). Additionally, by letting these specific groups get additional exposure or 'practice' with digital interfaces beforehand, their comprehension of the interface can improve from 46% to 80%.

4.3 Familiarity's main effect

Familiarity had a significant main effect across all conditions: the more familiar the interface metaphor was, the better comprehension score achieved. Familiarity helps reduce cognitive load by allowing users to apply other mental models to the familiar metaphor, and assume how interface elements work together. This frees up cognitive resources for addressing other design factors (i.e. complexity) or child factors (age, technology-experience).

5. Conclusions

"If children can't use educational technology effectively, they certainly won't learn through the process of using it" (Bruckman & Bandlow, 2002). This study identified four variables that showed significant effect on young children's comprehension of a novel interface: age, technology-experience, complexity and familiarity. The results show that by consistently addressing all four variables in both design and research of children's HCI, we can significantly improve the usability of interfaces for young children. Additionally, by having more examples of how these factors affect comprehension of interfaces in different contexts, we may be able to create a larger theoretical framework for age-appropriate design.

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