A COMPARATIVE ANALYSIS OF THE MEANING OF 'LEARNABILITY' FOR CHILD AND ADULT USERS

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ABSTRACT

The learnability principle relates to improving the usability of software, as well as the user's performance and productivity. The latter suggest that the principle was formulated mainly with the adult user group in mind. Children represent an important user group, but fewer guidelines exist for their educational and entertainment applications. This study compares these groups, addressing the question: 'Does learnability of software interfaces have a different meaning for children and adults?' A literature survey conducted on learnability and learning processes, considered the meaning of learnability across generations. In an empirical investigation, users aged from 9 to 12 and from 35 to 50 were observed in a usability laboratory while learning to use educational software applications. Eye tracking data was also recorded. Insights emerged from data analysis showing different tactics when children and adults use unfamiliar software, and revealing aspects of interfaces that they approach differently. Our re-interpretation of the learnability principle and the resulting design recommendations will help designers to distinguish the varying needs of users of different ages, and improve the learnability of their designs.

KEYWORDS

Learnability, Generational differences, Human computer interaction, Child computer interaction, Design guidelines, Usability.

1. INTRODUCTION

The classic principles and guidelines for software design were generally aimed at improving work performance and productivity – things that are more important for adults than for children (Pretorius, Gelderblom & Chimbo, 2010). Many design principles for adult applications cannot be applied to children's products, because the needs, skills, and expectations of these user groups differ drastically (Chiasson & Gutwin, 2005). Children represent an important user group and it is therefore important to identify design guidelines that are aimed specifically at educational and edutainment software for them. Various researchers and human-computer interaction (HCI) specialists have, however, proposed guidelines that are aimed at design for children (for example, Grammenos & Stephanidis, 2002; Fishel, 2001; Baumgarten, 2003; Gelderblom, 2008) and the research we report on in this paper is an attempt to augment these ventures.

Dix, Finlay, Abowd and Beale, (2004) provide interface designers with a comprehensive set of high-level directing principles with the aim of improving the usability of systems. Their principles are divided into three categories, namely learnability, flexibility and robustness. Learnability refers to the degree to which a user interface can be learnt quickly and effectively. The focus of this paper is to investigate the meaning of the learnability principle to establish whether it should be applied differently to software applications aimed at different age groups. The outcome of this comparison provides insights into aspects of software interfaces that adults and children approach differently. This knowledge is formulated in a way to help designers to better fulfill the needs of users of different ages. The results also contribute to the reformulation of the learnability principle in a way that distinguishes between adults and children.

The aim of our research was to compare the way in which children (aged 9 to 12) and adults (aged 35 and older) learn to use a new application. To this end we wanted to do the following:

- Identify aspects of software interfaces that adults struggle with that children have no problems with and vice versa.
- Look for patterns in the learning behaviour of adults and children respectively.
- Use the above to compare how children and adults learn to use software, thereby making a contribution to broadening the definition of the learnability principle.

A series of empirical studies were conducted with child and adult participants using software aimed at children, and software aimed at adults. Data was collected through interviews, observations, video recording and eye tracking. In this paper we report only on the studies that involved two software applications aimed at children.

The type of research discussed in this paper is descriptive, as it represents a picture of the specific details of a situation, social setting or relationship (Neuman, 2003). Rich descriptions of the behaviour of participants at the interface were used as the starting point for data analysis. Qualitative analysis methods, including the grounded theory approach to coding, were used to derive insights into the different meanings of learnability.

2. LITERATURE REVIEW

This section explores what other researchers have discovered in their research concerning the learnability principle and, more generally, how children and adults learn.

2.1 The learnability principle

Learnability has been defined as the time it takes users to learn how to use the commands relevant to a set of tasks or the effort required for a typical user to be able to perform a set of tasks using an interactive system with a predefined level of proficiency (Shneiderman, 1997; Santos & Badre, 1995; Nielsen, 1994; Dix, et al, 2004). Learnability comprises specific measurable attributes (Dix et al, 2004, Senapathi, 2005) and a system's learnability can be effectively evaluated by measuring these attributes in a real life context. In the context of HCI, learnability is concerned with interactive system features that assist novice users in learning quickly and also allow steady progression to expertise.

A number of researchers have identified principles that affect learnability (Preece, et al, 2007; Dix et al, 2004; Senapathi, 2005; Aspinall, 2007). Those originally identified by Dix et al. (2004), are predictability, synthesisability, familiarity, generalisability and consistency.

Predictability refers to the ease with which users can determine the result of their future interactions with the interface, based on the past interaction history (Dix et al, 2004). A system is easy to learn when it is predictable. Synthesisability is the ability of the interactive system to provide the user with an observable and informative notification about the operation state changes within the system (Aspinall, 2007). Users can assess the consequences of their actions when a system is synthesisable. The familiarity principle is concerned with the ability of an interactive system to allow a user to map prior experiences, either real-world or gained from interaction with other systems, onto the features of a new system (Dix et al, 2004). Familiarity impacts on the novice user's initial perception of the system and on whether the user can discover the required actions from their own prior experience.

Generalisability provides support for users to extend knowledge of specific interaction within, and across applications, to new, but similar situations (Dix et al, 2004). To support generalisability, consistency is essential. The system should offer the same or similar functionality in comparable situations. Consistent interfaces are easier to learn and use as they give the user confidence in using the system (Preece et al, 2007; Nielsen, 1994).

2.2 The learning process

Learning is the process of transforming experience, skills and attitudes and involves a number of different sub-processes. Learning is broader than education and can occur outside of the educational situations. A variety of learning theories and various definition of learning have been proposed. Below, we summarise some of these, and compare the way adults and children learn.

2.2.1 Learning theories

A learning theory is an attempt to describe how people learn, providing the vocabulary and a conceptual framework for interpreting the examples of learning that we observe (Siemens, 2006). It seeks to provide insight into the act of learning. Behaviourism, cognitivism and constructivism are the three main theories that will be described briefly below.

Behaviourists see learning as occurring through the observation of behaviour in a black box (Driscoll, 2000). Behaviourism is influenced by the nature of reward and punishment stimuli. Instead of focusing on the internal mental activities, behaviourists focus on observable behaviour. According to a behaviouristic view of learning, a learning result is indicated by a change in the behaviour of a learner (Venezky & Osin, 1991).

Cognitivism relates to the results of cognitive processes such as the formation of mental models, human information processing, metacognition, and self-regulation. Cognitivists see learning as information processing done internally (Driscoll, 2000).

According to De Villiers (2005), constructivism relates to personal knowledge construction and interpretation, active learning, anchored instruction, and multiple perspectives on an issue. The constructivist approach is based on the premise that, by reflecting on our experiences, we construct our own understanding of the world we live in. Learning occurs as learners 'attempt to make sense of their experiences' (Driscoll, 2000: 376).

None of these theories can be regarded as exclusively right or wrong. It is, however, necessary to know that constructivism is presently accepted as the more relevant of the three and that current education policies, education models and education practices primarily focus on constructivist learning.

2.2.2 Definitions of learning and skill acquisition

Learning is a process whereby a person moves from not knowing something to knowing something. It can be deliberate or incidental, it can be cognitive or practical, but it involves change with regard to knowledge, skills or attitudes (Jarvis, 2006). Rushton, et al (2003) explain that learning happens through synthesizing the skill or concept being acquired with prior knowledge, conditions of learning, and mental understandings. Learning has some element of risk because learners do not always know exactly where they will end up (Goffree & Stroomberg, 1989). It involves making choices where the activity structure is flexible and allows different pathways.

Skill acquisition is a form of learning. Cotton (1995) distinguishes between three types of skill: psycho-motor skills (that becomes automatic after a person has performed it repeatedly), perceptual skills (controlled, practiced and accurate and carried out by the senses) and cognitive skills (used in the process of acquiring knowledge). Playing computer games is a composite skill that includes aspects of all of these.

2.2.3 Comparison of adult and child learning

Learning in adults and children is qualitatively different, not just because the learning capacity of the brain gradually matures, but because their life situations are essentially different (Illeris, 2006). In childhood, learning is typically uncensored and trusting. Children develop their thinking abilities by interacting with other children, adults and the physical world. In adulthood, learning is fundamentally selective. Adults concentrate on learning things that concern work, careers, family and interests. Learning is motivated by a need to become more self-directed. Another important difference is that children have not completely developed cognitively, emotionally or physically.

Adults develop skills more effectively in cases where they understand why they have to learn and develop that skill. Children learn best when the learning is self-initiated, arising from their own inquisitiveness and interests, rather than when it is imposed on them (Woolley, 1997). Children naturally seek to make sense of their experiences and to find order and reliable patterns in what happens. It is important for children to learn which of their behaviours produce desirable effects and to eliminate those that do not (Ramey and Ramey, 2004).

Children are keen observers of other people and can be very good mimics (Thornton, 2002). They also learn by interacting with one another, playing together or solving problems together. Play is an important way in which children learn. It provides opportunity to explore and to have trial-and-error experiences in a safe and enjoyable setting (Ramey & Ramey, 2004). When an emotion is engaged, events and ideas are committed to memory more strongly. Children also learn a great deal from joining in and helping with activities conducted by adults or other children who are more experienced (Thornton, 2002).

The differences between the learning of adults and children that are particularly relevant to our research are:

1. Children often depend on adults for material and psychological support during learning, while adults depend upon themselves.
2. Adults are largely self-directed in that they are responsible for deciding what, when, and how learning will occur. This difference is relative and varies according to context (Leberman, et al, 2006).
3. Children perceive one of their major roles in life to be that of learner, while adults perceive themselves as doers who use learning to achieve success (Ference & Vockell, 1994). Adults learn best when they perceive the outcomes of the learning process as valuable and contributing to their own development and success.
4. Adults have more life experience than children and this provides them with a better foundation for learning. However, it can also be a hindrance and a child's lesser experiences can occasionally prove more beneficial. An adult can be less willing to explore new ways of doing things and this can hinder progress.

Part of our aim with this research is to determine how relevant such differences are in the context of learning to use an unfamiliar computer game. We next explain the methods used in this investigation.

3. RESEARCH QUESTION AND METHODOLOGY

3.1 Research Question

The research was guided by the following question:

Does learnability of software interfaces have a different meaning for children and adults?

3.2 Participants

Twenty-four people participated in the usability laboratory studies ─ 12 children from 9 to 12, and 12 adults aged 35 to 50. The participants were all volunteers. In the experiments, some acted as novices and some as experts. Five of the participants acted both as experts and novices as they were familiar with one of the games but not with the other. The children attend primary schools in Pretoria and the adults are all academic or administrative employees at a university in Pretoria. They all had moderately high, to high levels of computer literacy.

3.3 Software used in this Study

Two educational software applications were used, namely Timez Attack (Bigbrainz, 2005) and Storybook Weaver Deluxe 2004 (Broderbund, 2005).

Figure 1 shows a screen shot from Timez Attack. It is an educational application, cleverly disguised as a captivating game. Timez Attack teaches children aged seven and older the multiplication tables. Users navigate an avatar (a little green alien) through dungeons in search of golden keys to open doors. The keys take the form of multiplication sums. When a key is found, the program takes the user through a sequence of events that helps to systematically build up the answer to the sum. Timez Attack uses the third person shooter style genre of game play, but instead of weapons, answers to multiplication sums are used to defeat villains or open doors.

Storybook Weaver Deluxe 2004 is a software application for creating stories as shown in figure 2. Users can choose from a large selection of backgrounds to create scenes on the pages of their electronic story book and select from thousands of story characters and objects to create illustrations. Story text is typed into the text panel below the illustration. The user can also add background music and sounds to the page or story objects. If there is a microphone attached to the computer, the user can record a voice over for the story page.

Figure 1 Timez Attack

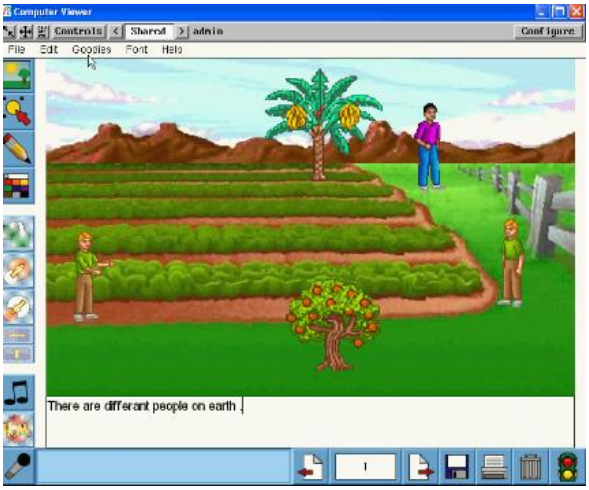

Figure 2 StoryBook Weaver

3.4 Data collection and analysis

A series of experiments was conducted in a formal usability laboratory, each involving a user learning a new application. The researchers observed different combinations of pairs of users (e.g. a child expert teaching an adult novice, a child expert teaching a child novice) and adult and child novices teaching themselves.

Data was collected through observation, eye tracking, and interviews. Observations were also video recorded for later analysis. It allowed us re-observe events repeatedly. With each repeated viewing, the researcher could change her focus somewhat and see things she had not seen previously (Fetterman, 1998).

Eye tracking is a technique for recording eye movement and eye-fixation patterns, and was used when single participants were teaching themselves how to use one of the software applications. We also conducted informal, semi-structured interviews with both the novice and expert participants after the sessions to discuss their feelings and reactions during the experiment. This helped to clarify the users' thought processes, and to explain why they struggled when they did.

An extensive five step data analysis process proposed by Terre Blanche and Kelly (1999) was followed. It involved:

1. *Familiarisation with and immersion* into the material gathered, reading (and watching) it repeatedly, with the objective of obtaining thorough knowledge of the collected data.
2. *Identifying themes* which then formed the basis from which the descriptions of the observations could be refined and reorganised.
3. *Coding*, whereby notes were scrutinised to identify instances of specific themes, or relevance to specific themes. We borrowed from Strauss and Corbin's (1998) three grounded theory coding processes, namely open coding, axial coding and selective coding.
4. *Elaboration* to explore the newly organised material to identify similarities and differences in the data that may lead to new insights – in this case, insights related to the difference between adults' and children's ways of learning.
5. *Interpretation and checking* to ensure that there were no weak points or contradictions.

4. RESULTS

The results provide insights into aspects of the learnability of software interfaces that adults and children approach differently. This section is organized according to the insights that emerged from the elaboration process. The insights are discussed together with their justifying evidence, as well as some possible implications for software design.

Insight 1: Children are more accepting of usability problems than adults.

This was shown, for example, by the reaction to an unexpected congratulatory message in Timez Attack. The message 'Congratulations: Checkpoint reached' incorrectly appears before the player has actually achieved any milestone in the game. Children ignored the message. They just waited for the message to disappear and continued with game play. Adults, however, were confused and questioned why they were being congratulated for doing nothing.

Evidence from StoryBook Weaver is the different reactions of the two groups to the puzzling choice of selection icons. Children were undisturbed when they had to use the +, and not √, to accept the selected story object (see Figure 3). They just clicked on both buttons until they got the desired effect. Adults, on the other hand, were frustrated when they did not get the desired outcome by clicking on √.

Figure 3 Buttons for selecting and adding objects

It shows that designers should not assume that a child's impression of usability is valid. They can be very forgiving and may not comment on obvious problems when asked their opinions. Products intended for children should be tested with adults in order to discover potential usability problems that may be overlooked when testing with children.

Insight 2: Adults tend to have fixed patterns as a result of their life experiences and can be less open-minded during learning than children. Children, on the other hand, learn in an ad hoc (unplanned) manner.

Children do not mind trying out things just to see what happens. They do not think anything can go wrong. Adults, on the other hand are more cautious, and tend to be more self-critical than children. Adults are rigid in what they expect of a user interface whereas children like to explore.

In Timez Attack, snails have to be caught before answering the multiplication sums. The process of locating the snails follows an unpredictable sequence of mouse moves. When child novices were playing the game, they moved the mouse at random, coming across the snails in the process, and eliminating them. Questions asked by the children are evidence of the above insight, for example:

'Does it matter which numbers I use on the keyboard?'

'Can I go the wrong way and see what happens?'

'I want to see what happens if I do not catch one of the snails?'

While playing Timez Attack, children tried out different actions just to get ahead in the game. Eye tracking data show that they focused on the Play button that would activate the game, while adult participants fixated on the instructions at the bottom of the screen. Figures 4 and 5 show a child's and an adult's fixation patterns respectively. The adult has noticeably more fixations on the screen which is an indication of uncertainty.

Figure 4 Fixations of child novice on opening screen

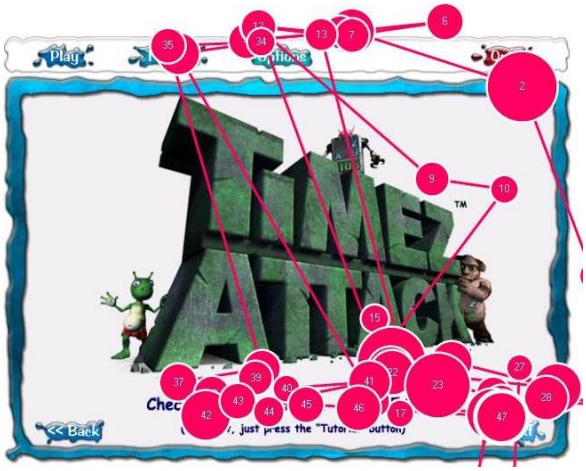

Figure 5 Fixations of adult novice on opening screen

In general, adults were more cautious than children in learning a new application. Cautiousness, as Salthouse (1991) points out, is 'one of the most frequently mentioned performance-limiting factors' (p 176). Adult novices hesitated to make any moves that they were unsure about, as their comments and questions show:

'What if I click the wrong door?'

'How do I make the avatar walk to the left without making a mistake?'

'What if I make a mistake and fall in a dungeon?'

Software designers should design applications that accommodate the different learning styles of different age groups. For example, there is need to accommodate the less instruction-dependent children. Software intended for children should include elements that facilitate independent learning. Software designed for adults, on the other hand, should provide detailed instructions on how to use the application. Applications designed for children should show greater tolerance for incorrect operation than applications designed for adults. Designers may work through a risk assessment to ensure the applications and their implementations do not expose children to unacceptable risks. If an application requires a very specific sequence of actions the interface should make this clear so that children do not follow the wrong trail.

Insight 3: Child novices can be faster than adult novices in mastering mouse and keyboard navigation skills during game play.

In Timez Attack, all the adults struggled to use the mouse/keyboard combination to walk the avatar through the dungeons. Examples of the emotional expressions of adult novices in reaction to mouse/keyboard navigation difficulties included:

'Ooooooooohmmmmmm!! What now?'

'Oh man what is the mouse doing?'

'Oh good grief! What must l do with this thing?'

Children displayed better dexterity than adults when using the mouse to navigate. Of the seven child novices who learnt how to play Timez Attack, only one experienced difficulty with navigation, and only initially.

If software is designed for all age groups, they should provide customizable user interfaces that enable users to choose the user interface controls to match their preferences. Also, designers should not assume that because adults generally have better hand-eye coordination than children that they will be better than (or just as good as) children at navigation.

Insight 4: Adults want to have a clear picture of the entire software application before they start using the application, whereas children just start using the application.

This insight is evidenced by how adult experts taught the novices. They would begin by asking the novice if they knew anything about the application and explained what the software was about, before giving instructions for using it and demonstrating it practically. Child experts immediately instructed novices on how to use the software applications and allowed the novices to participate from the start.

Child novices rarely asked for assistance during game play. They discovered things for themselves without any need for guidance. Their natural curiosity drove them to make new discoveries. Adult novices asked for help the moment they were given the chance to play the game. They were hesitant to try anything independently and asked many questions.

All the adult participants began by reading the tutorials of Timez Attack and StoryBook Weaver while only one child participant read the Timez Attack tutorials. This confirms that adults want a clear and complete picture of what is coming.

Designers should provide appropriate guided tours of the application for first-time adult users. Since children prefer to get on with it, designers should not rely on them using the tutorials. If both children and adults are expected to use the application, designers should provide customisable guided tours in order to accommodate the requirements of both types of users.

Insight 5: When learning to use a new software application, children are more comfortable learning from their peers than from adults. Adults, on the other hand, are not affected by the age of the person who teaches them, as long as the person demonstrates clear knowledge of what he/she is doing.

Child novices appeared very relaxed when they were being taught by a child expert. The children frequently interrupted the demonstrations with questions. During the interviews, when asked how they felt working with their peers, all the children indicated that they felt confident and relaxed. When an adult expert was teaching, the children showed signs of intimidation by failing to ask any questions as they did when they were being taught by a child expert. One of the children who asked a question to an adult expert only did so when the adult asked if he had any questions.

This implies that when developing training materials for software applications, designers should be aware of the effectiveness of peer tutoring for children. When applications are developed for use in a school laboratory or in any situation where adult supervision will be present, the design should not rely on the availability of adult assistance. When struggling, the children may not ask for help spontaneously. They may rather try to get by on their own or they will ask their peers.

Insight 6: Children often accept what they are learning regardless of its purpose. Adults find learning to be purposeful if it has meaning and adds value to their lives.

Children were obviously more engaged and did not get put off easily by usability and other problems. The fact that adults showed signs of frustration much earlier and often struggled where children did not, can be linked to the fact that the applications were not ones they would use voluntarily. Children and adults get more engaged and involved if they are using software that relates to them. Adults connect their learning of new software applications to life experiences that may include work-related activities, family responsibilities and even previous educational experiences. In Storybook Weaver, child novices produced pictures related to their fantasy worlds, whilst adult novices produced mature pictures related to their day-to-day work or social environment.

5. DISCUSSION

The main research question of this study relates to the possibility that learnability may have different meanings for users of different ages. We consider this in the discussion that follows, relating the sub principles of learnability (defined in section 2.2) to the insights gained through this study (discussed in section 4). We also discuss what we have learnt in terms of the learning process and end with some recommendations for design that emerged from the results.

5.1 Reinterpretation of the sub principles of learnability

The literature review established that a system would be easy to learn if it was predictable. Predictability allows users to know beforehand what will happen when they click on a menu item or press a key. Insight 1 showed, for example, that children did not consider the meanings of the two buttons in Figure 2 as critically as the adults did. They merely tried them out until one worked, while adults showed some confusion when the buttons did not function as they would have predicted. Elements relating to predictability were also evident from insight 2. Children used trial-and-error to play the game whilst adults relied on instructions. Eye tracking results showed that fixations of child novices were longest on the Play button whilst the fixations of adult novices were longest on the instructions.

A user interface that adheres to the principle of synthesisability allows the user to understand which user actions have led to the current state, what the system did to get there, and what the user should expect next. Insight 2 relates to synthesizability. It refers to the broader life experiences of adult novices that allow them to develop mental models that may enable them to overcome the difficulties of learning to use a new application. However, at other times, these mental models may be detrimental to learning. Adults' fixed patterns can cause them to be less open-minded than children to new learning. Children use whatever they learn through trial-and-error to construct cognitive maps of the workings of an unfamiliar software application.

Familiarity is the degree to which the user's own real-world personal experience and knowledge can be drawn upon to derive insights into the workings of an unfamiliar system. When the system has familiar elements, the user will relate it to similar, real-world situations or systems, thereby reducing the amount of cognitive burden to become adept at using it. Insight 2 also relates to familiarity. The insight suggests that adult novices learn by applying past experiences in their learning, while child novices have limited life experience to apply in learning new things.

A system is generalisable if users are able to use what they have already learnt to carry out new tasks. Insight 3 relates to generalisability. It suggests that child novices were faster than adult novices in mastering mouse and keyboard navigation skills. Besides youthful dexterity, as opposed to the general slowdown of motor co-ordination with age, the main source of performance advantage in mouse and keyboard mastery by child novices over adult novices could be found in the generalisability of mouse and keyboard skills mastered in other prior applications.

Consistency applies when the system behaves in the same way when comparable sequences of actions take place in similar situations. Consistent interfaces are easier to learn and use (Preece et al., 2007). They assist users in gaining more confidence in using the system and encourage them to try out exploratory learning strategies (Nielsen, 1994). Insights 2 and 4 support Nielsen's (1994) assertion that consistent user interfaces encourage exploratory learning strategies. If system feedback and responses are consistent, child novices will have more success in their exploratory approach to learning.

The findings of this study suggest different interpretations of the learnability principle and its sub principles for children and adults. To summarise:

Predictability is more crucial in adult products than in those aimed at 9 to 12 year olds. Adults need to be sure of what happens next and what they are allowed to do next, while children are more willing to try out different things and just explore. Children are less concerned about the effects of their actions than adults. Synthesizability has a different meaning for the two user groups since their differing levels of experience will influence the way they form mental models about the working of a system. When designing for children, designers should thus be aware that children may construct different mental models from what they (the adult designers) would expect.

A system that adheres to the principle of familiarity for adults may include elements with which children are not familiar with. On the other hand, the fact that children are exposed to technology from early on, may mean that new input mechanisms that they have been exposed to through computer games may be unfamiliar to older people. The consequences of generalisability and consistency on learnability may be different for each user group, but there is no indication from the derived insights that the two user groups understand the meanings of the two principles differently.

Not all the insights could be related to the existing sub principles of learnability. We have identified the need to incorporate the concept of 'engagement' into the definition of learnability, since the users' level of

engagement will determines their commitment to learn the application. This will be a topic for further research into the re-definition of the learnability principle.

5.2 The learning process

Literature on the learning process alludes to differences in the way that adults and children learn. Insight 2 highlights the differences in the life experiences of adults and children as the source of observed cognitive differences between adults and children. It also relates to how adults learn new things to their past life experiences.

Insight 6 relates to Von Glasersfeld's (1989) discussion of the theory of social constructivism, which emphasizes the importance of the learner being actively involved in the learning process. Children are simply happy to accept what they are learning regardless of its purpose, but adults appreciate learning if it gives added value and meaning to their lives.

Literature on the characteristics of adult learners, states that adult learners need to know why they should learn something before undertaking to learn it. Insight 4 relates to this characteristic when it refers to children trying out new things just to see what happens and not being worried that something might go wrong. Adults, on the other hand are more cautious, and tend to be more self-critical than children. Adults are rigid in what they expect of a user interface whereas children like to explore.

Our results thus show that the differences in how adults and children learn in general, do not always apply when they are learning to use a new software application:

- Whereas adults usually rely on themselves in the learning process, when they learned to use the software games in this study, they depended on the support of instructions and outside help more than children did.
- In these games adults were not noticeably more self-directed in their learning than children.
- Adults' broader life experience did not have a clear effect on their learning of the games. In some instances it hindered them rather than helped them. Children were more confident to learn through trial-and-error, while adults preferred to read instructions.

These findings on the differences between the general learning styles of children and adults could serve as basis for recommendations to application designers to better satisfy their intended end users.

5.3 Recommendations for design

The recommendations given below summarise the implications for design based on the results of this study:

1. Software should be designed so that, even if instructions are available, users can use the software without instructional guidance. Software intended for children should not rely on written instructions to users. Software for adults, on the other hand, should provide detailed instructions and Help facilities.
2. Designers should make instructions clearly detectable and well-positioned on the user interface so that users would be more likely to read them when it is essential for successful interaction. If adults will use the product, tutorials that give product overviews should be provided.
3. Designers should consider the coordination of mouse and keyboard use by both children and adults. Understanding the connection between moving a mouse and movement on a computer screen can take time to develop. Adults may also require help to master the motor control necessary if input devices are to be used for actions they are not used to.
4. Applications designed for children should show greater tolerance for incorrect operation than applications designed for adults.
5. Designers of software applications intended for adults should make the value of learning a new application apparent. Given the rationale for learning something, they will be more likely to invest time in it.
6. Designers should design software for a specific group based on that group's needs and goals. Different user groups have their own skills and abilities, therefore design principles for one group may not be applicable the other group. Designers should acknowledge that they as adults may not understand the

needs of child users. On the other hand, when designing for children they must test the usability of their designs with adults, because children are more accepting of usability problems.

6. CONCLUSION

The lack of sources in the literature that deals specifically with the learnability principle suggests a gap in the body of knowledge. This study was an attempt at filling that gap, but more work needs to be done to improve the granularity in the description of the of the sub principles. Specifically, better distinction between some of the principles, for example, generalizability and consistency, could be achieved through further research. The importance of 'engageability' to be incorporated into the definition of learnability has been identified as worthy of further investigation.

A limitation of the study was that the experiments were conducted in a usability lab that isolated participants in a controlled environment, where they could interact only with the facilitator and complete tasks with only the tools provided for them. This may have introduced bias into the results of the study. Users' behaviour can be influenced by the fact that they are being observed and some of the behaviour observed during the experiments may have been different in a natural setting.

External validity, or the generalizability of the study, is limited by the fact that there were only 24 participants. Although the children represented different cultural groups and home languages, they were all from two schools situated in relatively privileged areas. The adult participants were from the same work place, but they did represent a range of skill levels (from a full professor to a security guard) and cultural groups.

The study highlighted the need for software designers to distinguish actively between child and adult users. The results lead to reformulation and re-interpretation of the learnability sub principles to differentiate between the needs of adults and children and served as foundation for specific recommendations for design. We believe that the findings of this study will help to advance HCI practice and to improve the quality of software targeted at different user age groups.

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