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A review of mental models research in child-computer interaction

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Abstract

Research in cognitive science, science education, and developmental psychology has long investigating how children, based on their everyday experience, construct mental models of the world they live in. This paper provides a review of the research investigating the nature of mental models in the context of child-computer interaction, review elicitation techniques used within the field, and discusses its potential to further inform the design process. Exploring children's mental models of new technologies may bring about some further understanding in their cognitive and conceptual development, thus promting parents and teachers to guide them in exploring the new technological environment.

Keywords: mental models; development; child-computer interaction; design;

1. Introduction

As new technologies become increasingly embedded in everyday activities, it is common for young children to interact with dozens of digital devices throughout a typical day. Many spend hour-upon-hour learning about and manipulating sophisticated computer devices such as laptop computers, game consoles, cell phones, digital cameras, or audio players. All these technologies are now part of the "natural environment" where many children are born and raised today. While many adults struggle with comprehending and manipulating digital interfaces, today's young children enthusiastically approach these interfaces with little or no effort, although they may not completely understand how to use it, or what their implications are. Despite of a wealth of literature on mental models in human-computer interaction, few recent research studies are specifically addressing this issue in the framework of design

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and implementation of new technologies for children. While many papers would firmly state that exploring mental models in children interaction with technology is compulsory, little bibliographic references provide a systematic theoretical and methodological account on it. However, research in cognitive science, science education, and developmental psychology has long investigating how children, based on their everyday experience, construct an intuitive understanding of their social and physical world; nevertheless, less is known about how do children's intuitive knowledge about the technological world they live in is conceptualized and represented by their mental models: are there specific characteristics of mental models that might shed light on children's extraordinary ability to accommodate new technologies? how do children understand related concepts that are newly emerged and highly complex? Therefore, in this paper we intend to provide a short review of the research on the nature of mental models in child-computer interaction, with an emphasis on the methods used in externalising this kind of knowledge. We do belive that exploring children's mental models of new technologies may bring about some further understanding in their cognitive and conceptual development, and help designers learn emore about their playfulness, enthusiasm and the types of metaphors to include in the interface of new interactive devices (Uden & Dix, 2000). Children are not miniature adults (Druin, 1999), they have their own needs and goals which cannot necessarily be met by adult tools,while design principles formulated with adults in mind cannot be simply translated into new interaction contexts.

2. Mental models and child-computer interaction

"In interacting with the environment, with others, and with the artifacts of technology, people form internal, mental models of themselves and of the things with which they are interacting. These models provide predictive and explanatory power for understanding the interaction" (Norman, 1983, p.7). These models provide the cognitive structure that forms the basis of reasoning, decision making, and action. Mental models are dynamic structures that evolve as they constinuosly incorporate new information and widen the undestanding of the world based how it is experienced. A plausible hypothesis states that the degree children are able to process new information depends upon their existing mental models, as well. As Piaget would have probably rephrased it, building a mental model is an important component in accommodating to the world by equilibrating differences between what is "in the world" and what is "in the mind" (what is understood by the knower), by helping children to organise their knowledge about specific events, objects, and individuals according to their own immediate world of experience.

D. A. Norman (1983), who provided one of the first attempts to create a terminology for a human-computer interaction theory of mental models, suggests that mental models instantiate the structural relationship between objects and events thus allowing the user to plan actions, explain, and predict external events. This intuitive knowledge provides explanations of natural phenomena which are frequently different from the currently accepted scientific explanations (see for instance, Vousniadou, 2002), but tend to be resistant to change since new information is sought in ways that depend on and are limited by their current mental model and learning goals (Tweney, 1987). In other words, children understanding of the world is build based upon prior knowledge and experience, even though this information may be fragmentary, inaccurate or inconsistent (Norman, 1983). For instance, a child may hold a belief that balls are round, inflatable, and made to bounce. However, this child may encounter a football (an ellipsoid) that is kicked or thrown, or a bowling ball that is solid and has holes drilled into for the purpose of rolling rather than bouncing (Vosniadou & Brewer, 1992). This new knowledge might be integrated into a new, more complex, mental structure about the shape, substance, form, function of balls, together with the novel modalities the child knows he or she can use the object. As seen also in the example above, mental models tend to be functional rather than complete or accurate representations of reality (Van der Veer, 1994). For instance, the user mental model of how a telephone works might include: pick up the phone to initiate a connection, dial the number s/he wants to call, hear the phone on the other end ringing, and then the other person answers. It is a simplified representation of a complex reality, not very accurate (the ringing heard by user is not actually produced by the other telephone), but good enough to operate the device and plan the next steps in the course of interaction. As we will see further on, mental models typically act as inferential frameworks that allow people to use analogies in order to talk about something new in terms of what is already known. In terms of Gentner & Gentner (1983), analogical thinking allows people to generalize on the basis of past experiences and use this generic information in new contexts. Users always have some mental model of the system using a variety of metaphors and analogies. Of course, interface metaphors suitable for adults may not be allways appropriate for children, as one of the main design challenges in child-computer interaction is discovering useful metaphors that can support children´s understanding of the underlying functionality of technology (Bruckman & Bandlow, 2002). Futhermore, if designer´s conceptual models of the target system do not match their mental models, it is rather difficult to force them to accept such models. Therefore, a primary goal in designing technology for children is to create and support an appropriate and coherent mental model of the operations and organisation of the computer system. Successful interface metaphors should be simple systems that do not require children to learn and remember many rules and procedures, while drawing heavily on the children's knowledge of the world around them, in order to established connotations that allow them to predict the results of their action in advance (Uden & Dix, 2000).

3. Mental models elicitation techniques

Designing user-friendly devices for children is a very demanding task. It involves understanding how children understand their world (how their mental models look like), as children's knowledge of technology provides a glimpse into the future user's mindset (Oleson et al, 2010). Good design is embodied and determined by the quality of the mapping between the system image and the resultant user's mental model (Norman, 1983). Therefore, the very first step in the design process aims to identify and assess these models through familiarity with the children's background or by interviewing the children. It is the goal of the designer to seek a target that matches with the mental model, thus facilitating learning (Uden & Dix, 2000). Mental model is a concept intrinsically built-in the development of human computer-interaction (HCI) as a field of research and practice. In fact,"the actual dawn of user interface design first happened when computer designers finally noticed, not just that end-users had functioning minds, but that a better understanding of how these minds worked, would completely shift the paradigm of interaction" (Kay, 1990, p.58). However, the task of extracting and analysing users` mental models has allways been challenging. In the case of child-computer interaction challenges are expected to be even higher, since children themselves often have difficulty articulating exactly what is "in their mind". Not surprisingly thou, little bibliographic references points out towards research explicitly investigating how children construct and use mental models of the various interactive devices that are nowadays part of their environment. A variety of elicitation techniques have been used in the field of human computer-interaction, and also in working with children, in order to inform the design process. Some procedures are designed to directly elicit a representation of user understanding of a given issue. Participants may be asked to draw a diagrammatic representation of their mental model, using pictures, words, and symbols, or they may be provided with existing concepts on a set of cards and asked to arrange them into a representation. Other procedures require the researcher to re-create, or infer, the mental model from oral interview data or questionnaire data (indirect elicitation techniques). The basic methodology most researches uses in investigating mental models consists in asking users specific questions about a specific technological device they use to perform specific tasks on a daily basis, and eliciting drawings in the context of a teach-back individual interview. Developed by Pask in the framework of the "conversation theory" (Pask & Scott, 1972), it consists in asking the student to tell /teach an other person, in his own words, what he believes a topic to be (how he or she understands it). Van der Veer (1994 etc.) extended the technique, transforming it in a hermeneutic method to provoke the user to externalise his/her mental model or representation(s) of the system he or she interacts with. In the teach-back scenario, participants are asked (individually) to teach to an imaginary "colleague" how to solve the problem stated in the teach-back question. For instance, "Teach your colleague how to print out a page using this computer device". In order to respond the teach-back question, children are encouraged to externalise their knowledge about the system by writing, making diagrams, or drawings. Among other utilities, teach-back method is suitable for detecting individual differences in mental models: type of knowledge (declarative, procedural, strategic); various forms of representations, such as lists of commands, verbal descriptions of task components, flow charts of semantic components, descriptions of keystrokes etc.; metaphors, since children naturally tend to relate new information to existing knowledge, often by associating them with other physical objects; structural consistency / inconsistency: of the concepts in a knowledge domain; structural fragmentation /coherence of knowledge integrated in mental model. (Van der Veer, 1989, 1990). In her work on mental models, Stella Vosniadou (1992; 2002) also points out how using specific prompting questions we will extract the relevant concepts (both semantic and procedural, both naïve and scientific) that are relevant for the specific situation. As Van der Veer notes, teach-back is a technique that focuses on instantiated knowledge (1994; 2002; etc.). In other words, the type of representation it focuses on may differ dependent on the instruction. For instance, in a classic study of Kurland & Pea (1985), children (eleven- to twelve-years-old) were asked to give a verbal account of how a Logo procedure would work, then to simulate the running of the program line by line by using a graphic turtle "pen" on paper. Beyond mistaken mental models about recursion, authors found these to involve atomistic thinking about how programs work, assigning intentionality and negotiability of meaning as in the case of human conversations to lines of programming code, and application of natural language semantics to programming commands. More recently, in Oleson et al (2010), children were interviewed about their mental models of computers. The experiment was duplicated at a ten years distance (1999, 2009) proving an increased ability of children as young as 6 years of age to generated these analogies at a younger age. Furthermore, some interesting differences were noted between the analogies generated in the two experiment as a function of time: while children interviewed in 1999 were more likely to describe perceptual qualities of computers (i.e. shape), those interviewed in 2009 were more likely to relate computers with other familiar devices (i.e. cell phones and entertainment devices). Most children are able to create representational drawings of objects around their third birthday; late, when children learn to write, they can use words or even design arbitrary symbols to refer to objects. Recent studies employing drawings in exploring how children understand technologies may offer important insights in how to use such data. Studies in science education, like the one presented by Prokop et al (2009) illustrates how information can be obtained from purposeful drawings and has advantages for example due to time saving or simplicity of scoring over oral questioning or writing tasks. On the other hand, limitations do exist: some children lack manual dexterity skills or the mental agility to produce a correct record of their mental model ("special instruction" might be required in order produce better drawings): the drawing is the expressed model which may or may not coincide with the model proposed by the designer.

4. Conclusions: children understanding vs adult expectations

With the emergence of children as an important consumer group of technology, it is critical for parents and teachers to support children in ways that are useful, effective, and meaningful for their needs. The development of any technology can only be successful if the designers truly understand the target user group. As obvious as this may seem, designers of new technologies for children seems to forget that young people are not “miniature adults”, but an entirely different user population (Bruckman & Bandlow, 2002). For instance, in designing a new search tool for 5-6 years old children, Uden & Dix (2000) were confronted with the mismatch between the children mental models and the adult model (the conceptual model of the interface): “We thought we understood them when we talked with them, but our mental models were very often not the same as theirs, which resulted in a mismatch between the conceptual model and their mental models. This mismatch caused great difficulty for them in being able to recognise the icons correctly (n.n. designer´s conceptual model). Children are experts at being kids. They could not offer us a list of what they wanted to see or use because they are not that self-aware or articulate about their needs” (p. 284-285). Going one step further, the immediate inference would state that in order build new technologies that empower children, respect their ability to challenge themselves and the question the world around them, and offer children control of a world they live in, designers need to understand how children’s intuitive knowledge about the technological world they live in is conceptualized and represented by their mind. By exploring children’s mental models of new technologies designers may better understand their cognitive and conceptual development, while prompting parents or teachers to guide and support their children in exploring the new technological environment.

References

Bruckman, A., & Bandlow, A. (2002). *Human-computer interaction for kids.* In *The human-computer interaction handbook: fundamentals, evolving technologies and emerging applications* (pp. 428-440): L. Erlbaum Associates Inc.

Druin, A. (1999). *Children as Our Technology Design Partners.* In Allison Druin (eds), *The Design of Children’s Technology* (pp. 51-72), Morgan Kaufmann: San Francisco, CA., 1999.

Gentner, D., D. R. Gentner, D.R. (1983). *Flowing waters or teeming crowds: mental models of electricity. in* D. Gentner & A. Stevens (Eds.). *Mental models (pp* 99-130). Lawrence Erlbaum, Hillsdale, New Jersey, USA.

Kay, Alan C. (1990). *User interface: A personal view.* In Brenda Laurel (Ed.), The art of human-computer interface design (pp. 191-207). Reading, MA: Addison-Wesley Publishing.

Kurland, D.M., Pea, R.D. (1985). *Children´s mental models of recursive logo programs*. Journal of Educational Computing Research, Vol. 1(2), 235-243.

Oleson, K.E.; Sims, V. K.; Chin, Matthew G.; Lum, H. C.; Sinatra, A. (2010) *Developmental Human Factors: Children's Mental Models of Computers*. Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 54 (4), 1450-1453.

Norman, D. A. (1983). S*ome observations on mental models*. In D. A. Gentner, & A. A. Stevens (Eds.). Mental models. Hillsdale, NJ: Erlbaum.

Pask, G. & Scott, B. C. E. (1972). *Learning strategies and individual competence*. International Journal of Man-Machine Studies, 4, 217-253.

Prokop, P., Fanc□ovic□ová, J., Tunnicliffe, S. D. (2009). *The effect of type of instruction on expression of children’ s knowledge*. International Journal of Environmental & Science Education. Vol. 4, No. 1, January 2009, 75-93

Van der Veer, G. C., Kok, E. Bajo, T. (1994). *Mental models of computer systems: visual languages in the mind.* In: M.J. Tauber, D.E: Mahling, F. Arefi (eds) *Cognitive aspects of visual languages and visual interfaces* (pp. 3-40). Elsevier Science B.V., Amsterdam.

Puerta Melguizo M.C., Chisalita C., & van der Veer G.C. (2002). *Assessing users mental models in designing complex systems*. Proceedings of IEEE International Conference on Systems, Man and Cybernetics 2002. Hammamet, Tunis. IEEE.

Vosniadou, S., Brewer, W. (1992). *Mental Models of the Earth:A Study of Conceptual Change in Childhood*. Cognitive Psychology 24, 535-585.

Vosniadou, S. (2002). *Mental Models in Conceptual Development*. In L. Magnani & N. Nersessian Model-Based Reasoning: Science, Technology, Values, New York: Kluwer Academic Press.

Uden, L., Dix, A (2000). *Iconic Interfaces For Kids On The Internet.* IFIP World Computer Congress (pp. 279-286), Beijing, August 21-25, Kluwer.