Learning from HCI: Understanding Children's Input Behaviors on Mobile Touchscreen Devices

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Abstract: We posit that building effective educational technology requires elements from two fields of research: learning sciences (LS), for effective pedagogical interventions, and human-computer interaction (HCI), for usable interactive experiences. In this paper, we present our work, grounded in HCI methods, to understand patterns in children's input behaviors in both the touch and gesture modalities on mobile touchscreen devices. We describe the contributions of this work and how they can assist learning sciences researchers to build more effective educational technology, especially on interactive surfaces. We present suggestions for how the integration of HCI and LS research can lead to educational technology capable of adapting to expected user behaviors and provide a more seamless, natural learning experience.

Introduction

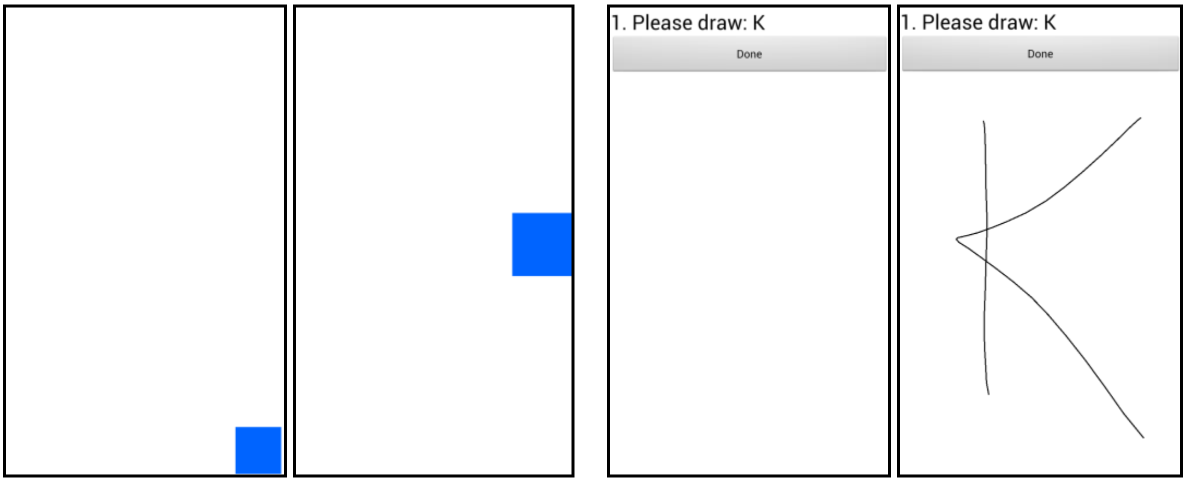
The widespread adoption of mobile touchscreen devices such as tablets and smartphones brings the potential to use these devices in the classroom to provide *situated* (learning in context, (Anderson, Reder, & Simon, 1996)) and *personalized* (individual and customized learning, (Cordova & Lepper, 1996)) learning environments for children (Anthony et al., n.d.). To develop effective learning environments for mobile touchscreen devices, researchers must consider both instructional and pedagogical design recommendations from the field of learning sciences (LS) and interface and interaction design recommendations from the field of human-computer interaction (HCI). Historically these two fields have been distinct with only few researchers and projects bridging the gap (Rick, Horn, & Martinez-Maldonado, 2013).

In this paper, we present our work to understand patterns in children's input behaviors on mobile touchscreen devices, and describe the ways in which the HCI methods we use can be adopted to build more effective educational technology and learning environments. We argue that neglecting to consider HCI elements when designing educational technology can actually lead to poorer learning as a result of frustration and other difficulties experienced by users due to poor interface and interaction design decisions. Our work particularly applies to learning environments deployed on interactive surfaces, but we discuss relevant features of our HCI methodology that can have broader impact on the design of educational technology in general. The contributions of this work will lead to educational technology that is able to anticipate and adapt to user input behaviors, providing a more seamless and natural learning experience.

Human-Computer Interaction Methodology in the MTAGIC Project

Through our *Mobile Touch and Gesture Interaction for Children* project, or MTAGIC ("magic"), we are building a foundational understanding of (a) the ways in which children use touch and gesture input on mobile touchscreen devices, and (b) the differences between children's input and adults' input in these modalities (http://mtagic.wordpress.com). We have collected data from over 70 participants including children ages 5 years to 17 years and adults ages 18 years to 33 years. To explore input patterns on mobile touchscreen devices, we built simple applications that ask users to touch onscreen targets (Target Task) and make surface gestures (Gesture Task).

Figure 1 shows screenshots of the task interfaces we have used in our studies. Our applications were designed to isolate individual input actions, and they log everything the users do as they interact with the application. The Target Task presented square targets of various sizes and at various locations onscreen which the users were asked to touch; the application automatically moved on to the next target when a successful touch was registered (e.g., touch was within the visual boundary of the target). The Gesture Task prompted the users to enter several examples of each of 20 gestures by drawing onscreen with their finger (e.g., letters, numbers, shapes, and symbols). For more information on these tasks, see (Anthony et al., n.d.; Anthony, Brown, Nias, & Tate, 2013; Anthony, Brown, Nias, Tate, & Mohan, 2012).



(a) Target Task Interface (b) Gesture Task Interface

Figure 1. Samples of the task interfaces we have used in our work.

We have analyzed the data both at a high level (i.e., just comparing children of all ages to adults ages 18 and up, (Anthony, Brown, et al., 2012; Brown & Anthony, 2012)) and at a more fine-grained level (i.e., comparing children of different age groups, (Anthony et al., n.d., 2013)). When we have compared children of different ages, we typically divide the children we have worked with (school age and above) into four age groups: 5 to 7 years old, 8 to 10 years old, 11 to 13 years old, and 14 to 17 years old. We identified these age groupings based on developmental psychology literature (e.g., (Piaget, 1983)), typical school age groupings in the United States: elementary school (5 to 10 yrs), middle school (11 to 13 yrs), and high school (14 to 17 yrs), and our experience conducting HCI research with children (Anthony et al., n.d., 2013).

Our key findings so far have included the following contributions to understanding the usability of touch and gesture interaction for children.

Touch Interaction

Children are *less accurate* when touching onscreen targets than are adults (Anthony, Brown, et al., 2012; Brown & Anthony, 2012). In fact, when considering children by age group, the younger the children are, the more attempts they take to touch the same target (Anthony et al., n.d.). Furthermore, children tend to have *more trouble with smaller onscreen targets* than do adults (Anthony, Brown, et al., 2012; Brown & Anthony, 2012); and again, the younger the children, the more difficulty small targets pose (Anthony et al., n.d.).

Gesture Interaction

Children's *gestures tend to differ* from adults' in significant ways, such as using more strokes to make the same gesture and making gestures larger and slower (Brown & Anthony, 2012). Furthermore, when considering children by age group, more subtleties emerge in gesture feature differences between age groups (Anthony et al., 2013). In addition, children's *gestures are more poorly recognized* by automatic gesture recognition algorithms (Anthony et al., n.d., 2013; Anthony, Brown, et al., 2012; Brown & Anthony, 2012), in part due to the differences in how these gestures are made. Looking in more detail, we find that there is a strong positive correlation between the age of the child and recognition accuracy (Anthony et al., n.d.; Anthony, Brown, et al., 2012): the *age of the child alone is a strong predictor of recognition accuracy*.

Based on these and other findings, we have developed a series of design recommendations that provide interface and interaction design strategies to accommodate these differences and improve children's success with touch and gesture input modalities across contexts. We include a high-level summary of the recommendations in Table 1. For more information about these recommendations and their basis in the data, see (Anthony et al., n.d., 2013; Anthony, Brown, et al., 2012).

Table 1. Design recommendations for touch and gesture interaction based on our studies with children and adults (Anthony et al., n.d., 2013; Anthony, Brown, et al., 2012).

Interaction	**Strategy**	**Design Implication**
Touch and Pointing	**Prevent unintended touch interactions (improve touch accuracy)**	Use timing and location of touches and interface widgets to identify and ignore holdover touches (corollary: improve interface responsiveness to prevent holdovers).
		Use consistent, platform-recommended target sizes.
		Increase active area for interface widgets to allow slightly out-of-bounds touches to register and activate the intended widget.
		Align targets to edge of screen, or count edge touches.
Gesture	**Tailor gesture recognition for children (improve recognition accuracy)**	Train age-specific recognizers to improve accuracy on children's gestures.
		Test new gesture sets with the target recognizer in advance.
		Develop child-specific recognizers from the ground up.
		Allow recognizers to learn over time and adapt to an individual child's gestures.
	Support children's conceptual models of gesture input (improve design)	Design gestures and gesture sets that make conceptual sense to children and are easy for them to execute.
		Avoid gestures unfamiliar to children.
		Provide visual feedback for surface gesture interaction on mobile devices.

Why Learning Science Needs Human-Computer Interaction

The methodology we have followed on the MTAGIC project uses empirical methods from HCI to understand how interaction with mobile touchscreen interfaces can be challenging for children. We have conducted laboratory studies to elicit examples of input behaviors from children of different ages in order to characterize the input patterns of children when they are using these mobile touchscreen devices. We posit that a foundational knowledge of children's input behaviors is necessary to design successful educational technology.

Prior work has shown that children have trouble making the smooth movements required in today's interfaces, such as drag-and-drop on both mobile devices and desktop computers (Brown, Hatley, Bonsignore, & Druin, 2011; Inkpen, 2001; Joiner, Messer, Light, & Littleton, 1998). Our work has shown that children's gestures exhibit patterns of execution that cause them to be recognized inconsistently by today's technology (Anthony et al., n.d., 2013; Anthony, Brown, et al., 2012; Brown & Anthony, 2012). In order for a learning environment to respond to student input and provide the right level of pedagogical support, the system must be able to understand and interpret what the student's input means. For example, if the child must try many times to get the system to accept his or her desired target widget (e.g., a menu item or touch-enabled button), the child may get frustrated and abandon the system. Also, if the system's gesture recognition component cannot confidently determine the gesture a child is entering, it cannot offer the appropriate feedback to the child and, consequently, the child may get frustrated and abandon the system.

Previous work at the intersection of HCI and LS has found that it is possible to reduce the impact of recognition and interpretation errors during learning-oriented interactions by designing the interaction to explicitly avoid involving the child in correcting the system's recognition errors (Anthony, Yang, & Koedinger, 2012). Thus, we argue that learning environments can and should make use of HCI interface and interaction design methods and techniques to design and develop interfaces that allow students to focus on learning, rather than on interacting.

Conclusion

We have presented an overview of our foundational work on HCI techniques for child-computer interaction on mobile touchscreen devices that can be used to build more effective educational technology. We have described the challenges that emerge when HCI principles are not considered during design of such learning environments. Building such adaptive learning systems also requires elements from learning sciences, such as instruction, pedagogy, cognition, and more, to complement the HCI elements.

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