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Hidden symbols: How informal symbolism in digital interfaces disrupts usability for preschoolers☆

Alexis Hiniker*, Kiley Sobel, Sungsoo (Ray) Hong, Hyewon Suh, India Irish, Julie A. Kientz

Human Centered Design and Engineering, University of Washington, Seattle, WA, USA

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ABSTRACT

Linking a symbol to the object it represents is a skill that develops gradually over the first few years of life. However, prior work shows that frequent use of this capacity makes it unintuitive for adults to recognize it as a challenge for young children. We hypothesized that this disconnect would manifest in software interfaces designed for young children, such that applications would embed symbols that the target audience would fail to understand. We conducted a randomized controlled trial with 34 preschoolers between the ages of 2 and 5 to assess their ability to work with user interface elements that require symbolic mappings. In particular, we assessed, (1) symbolic progress bars and (2) demonstrations of touch interactions by an on-screen cartoon hand. We found that these techniques are entirely inaccessible for children under 3 and that they require specific design choices to facilitate understanding in children between the ages of 3 and 5. Among a sample of 94 popular apps targeting children in this age range, we found that these symbolic techniques are incorporated into 44% of apps for preschoolers. We further found that embellishing symbolic elements with visual detail, a common practice in apps for preschoolers, increases children's cognitive burden and is an additional barrier to performing the symbolic mappings necessary to use these interfaces. We present design alternatives that make these prevalent user interface elements accessible to this user group.

1. Introduction

More educational mobile and tablet applications are designed for children under 5 than for any other age group (Shuler et al., 2012), yet designers targeting young children routinely draw on design paradigms developed for adult users. While some design choices may work well for users of all ages, prior work has shown that not all standard interaction patterns are appropriate for technology's youngest consumers (Hourcade, 2008).

In this investigation, we examine common interaction techniques in mobile applications for children that expect users to understand symbolic representations. Mapping a symbol to its referent requires simultaneous mental representations of the symbol, the referent, and the link between them, and forming such representations is a skill that emerges over the first few years of life (DeLoache et al., 1997). Despite the mental gymnastics that go into such a feat, adults interpret symbols so frequently and automatically that it is unintuitive for adults to think of this as a capacity that must be acquired (Uttal, 2003). For example, adults using a globe easily understand the globe to be both: (1) a physical object in its own right and (2) a symbolic representation of Earth, and they fluidly and automatically link these two understandings. Given the ease with which adults perform symbolic mappings, we hypothesized that user interface elements designed by adults may often have an embedded and unintended assumption that this skill comes easily to users. Given prior work demonstrating that very young children struggle to perform these mappings (DeLoache, 1989), we further hypothesized that this assumption would make certain user interface elements inaccessible to children.

As evidence that this gap between adult and child understanding is counterintuitive, we conducted a preliminary investigation examining 94 popular apps for preschoolers for evidence of user interface (UI) elements that require symbolic mappings. We selected two common elements: (1) progress bars, where the fill in the progress bar symbolizes the child's progress toward a goal, and (2) on-screen cartoon-hand demonstrations showing the child how to interact with the UI, where the cartoon hand symbolizes the child's hand. We predicted that both would be challenging for preschoolers.

We then conducted an experimental study to evaluate young children's ability to interpret each of these UI elements. By

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* Correspondence to: University of Washington, 428 Sieg Hall, Box 352315, Seattle, WA 98195, USA.

E-mail addresses: alexisr@uw.edu (A. Hiniker), ksobel@uw.edu (K. Sobel), rayhong@uw.edu (S.(Hong), hyewon25@uw.edu (H. Suh), indiai@uw.edu (I. Irish), jkientz@uw.edu (J.A. Kientz).

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selecting two elements that are visually dissimilar, serve unrelated purposes, and demand differing interactions from the child user, we aimed to isolate the effects of symbolic representation on children's understanding and thereby draw conclusions about children's ability to work with symbolic UI elements generally. Given a significant body of prior work showing that the capacity for symbolic representation develops over several years with significant gains between the ages of 2;6[1] and 3;0 (DeLoache, 2004), we conducted this investigation with preschool children between the ages of 2 and 5. We assessed participants' ability to successfully interact with interfaces with and without symbolic representation and measured the extent to which manipulating this property influenced children's understanding of the functionality of these interface components. Over three experiments, we explored the following research questions:

R1: Are toddlers and preschoolers able to interpret symbols commonly used in tablet applications for young children?

R2: How does this ability change with age?

R3: What are the design implications of children's emergent capacity for interpreting symbols?

To date, this broadly relevant challenge for young children has not been translated into concrete design recommendations for digital interfaces. Though others have speculated that children's challenges with symbolic representation could affect their ability to use digital interfaces (Antle, 2007; Hourcade, 2008), to our knowledge, this is the first empirical investigation to assess the challenges that common UI elements pose to children who have not yet acquired this capacity. We also provide the first documentation of the extent to which these challenges are disruptive to these child users and how designers can best support this user group.

2. Related work

2.1. Designing interfaces for adults versus children

A large body of prior work has investigated the ways in which interfaces can best accommodate the physical and behavioral needs of children, contrasting these design principles with those used when building interfaces for adults. Preschoolers benefit from touchscreen interfaces more than adults (Scaife and Bond, 1991), as they struggle to use mice and keyboards but can use direct-manipulation touch interfaces and master simple gestures as early as age 2 (Aziz et al., 2013; Hourcade et al., 2015). Children's gesture-performance and touch interactions improve steadily between the ages of 3 and 6, though adults are still 30% more successful in performing gestures than children in this age range (Vatavu et al., 2015). One study documented that at age 4, children were able to learn and successfully perform all of the seven common touchscreen gestures the researchers attempted to teach them: tap, flick, slide, drag and drop, rotate, pinch and spread (Aziz et al., 2013). Children in this age range (3–6) are also capable of learning to use a stylus, though they still suffer from usability issues that adults do not face (Couse and Chen, 2010). Other work demonstrates that between the ages of 8 and 11, school-aged children approach adult-like maturity in their performance of basic one-handed gestures such as tap, drag, swipe, and pinch (Aziz et al., 2013; Rust et al., 2014), but that even older children and teens still perform complex and custom gestures less skillfully than adults (Anthony et al., 2012; Brown and Anthony, 2012).

In addition to work examining children's physical usability challenges, other HCI research has examined the cognitive disparity between adults and children and its impact on their use of interfaces. McKnight and Fitton (2010) evaluated the effectiveness of interface-embedded language and terminology choices in written and audio instructions for 6- and 7-year-olds. They report that at this age children are unfamiliar with touchscreen terms such as “select” or “press and hold,” but are able to understand terms with real-world applicability, such as “slide” and “swipe.” Based on their analysis, the research team developed a set of design guidelines for creating mobile device interfaces for children age 7–10 (Mcknight and Cassidy, 2010). Other prior work has documented common ways in which websites are inaccessible to children between the ages of 3 and 5 (Gutierrez et al., 2015), difficulties that preschoolers have in responding to prompts to perform specific interactions (Hiniker et al., 2015), and struggles of school-age children in deciphering search results (Druin et al., 2009). Our work builds on these prior investigations by studying a known cognitive difference between young children and adults that has not yet been explored from the perspective of HCI.

2.2. Interaction design and theories of child development

When designing interfaces for children, existing theories of child development can provide valuable guidance (Wyeth and Purchase, 2003), and extensive, concrete design implications have been drawn from developmental theory (Chiasson and Gutwin, 2005). For example, Piaget's constructivist learning theory was the foundation of Papert's constructionism and has been the basis of numerous educational technologies (Blikstein, 2013; Kafai and Resnick, 1996). Gelderblom and Kotzé (2009) extracted 10 principles of interaction design for children by broadly scouring literature on child development and educational theory, distilling recommendations such as enabling children to go directly to their favorite parts of a system to repeat favorite content, and designing with the assumption that young children will not remember audio instructions. Hourcade (2008) provides a survey of both child development and design principles for children's technology in his highly cited manuscript, “Interaction Design and Children.”

Researchers have used such implications for design to inform the creation of novel technologies. Ryokai and colleagues developed e-books that incorporate elements of pretend play, an evidence-based practice for nurturing social and emotional development (Ryokai et al., 2012). Antle (2007) created the Child Tangible Interaction framework (CTI), which supports developers in creating digitally enhanced manipulatives for children under 12 and accounts for developmental changes in spatial awareness, embodied cognition, and understanding of semantics that children acquire as they grow. Others have leveraged Vygotsky's “zone of proximal development” as theoretical grounding for the creation of virtual agents, digital tools which assist children in performing tasks they understand but cannot yet perform without assistance (Marco et al., 2009).

We leverage this well-established approach by applying the *dual representation* theory of symbolic understanding (described next), and prior knowledge of its developmental trajectory, to the design of visual interfaces. By assessing children's ability to work with standard digital interface elements that employ symbolic constructs, we are able to define guidance for designing to accommodate young children's emerging abilities in this area.

2.3. The theory of dual representation

An extensive body of prior work by DeLoache and colleagues demonstrates that the ability to mentally maintain a symbol, its referent, and the mapping between them is a skill that develops

[1] We follow traditional linguistic notation where age is reported in yy;mm format (e.g., 2;6 represents 2 years and 6 months) (Baron, 1993).