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Do gestures matter? The implications of using touchscreen devices in mathematics instruction

Adam K. Dubé [a, *], Rhonda N. McEwen [b]

[a] McGill University, Canada
[b] University of Toronto, Canada

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ABSTRACT

Touchscreen devices are increasingly used in education and are a predominant tool for everyday knowledge search. An assumption about the nature of touchscreen devices is that users *intuitively* understand them, which improves access to knowledge. Using a framework that includes concepts from cognitive psychology, information studies, and communication theory we explored whether users' physical interactions on a touchscreen device have consequences for their conceptual understanding of content – in this case mathematics. In the present study, adults ($n = 40$) completed a number line estimation task on a tablet computer (on the line 1|——————|10, place a mark at 7) by either touching the screen in a singular location (tap) or by dragging their finger across the line to the desired location (drag). All participants then went on to use the drag gesture to complete two more tablet computer mathematics tasks assessing understanding of the continuous nature of numbers. Participants in the drag condition were more accurate on all three tasks, suggesting that the continuous nature of the gesture reinforced their continuous understanding of numbers. Gestures may influence understanding of content learned from a touchscreen.

In the consumer electronics world descriptors such as 'easy to use', 'accessible', and 'intuitive' often accompany the promotion of touchscreen devices, defined here as electronic devices with visual displays that are controlled through multi-touch gestures using a finger(s) or a stylus. These claims have fostered several assumptions about the nature of users' interaction with touchscreen devices, including the notion that users' intuitive engagement with touchscreens improves their understanding of content. Touchscreens are perceived to be intuitive because they are controlled by simple physical interactions and gestures that appear to require a low degree of formal instruction (i.e., touching the screen with an index finger). These devices are becoming a predominant means by which everyday people engage in information access (PEW Research Internet Project, 2014) and are increasingly being used in educational settings (Barack, 2011; Campigotto, McEwen, & Demmans Epp, 2013; Ludwig & Mayrberger, 2012). In particular, tablet computers are a type of a touchscreen device increasingly being used for mathematics education both in homes and in schools. According to a recent study of the education apps category on iTunes, four of the top five applications are for science, technology, engineering and mathematics subject areas, with mathematics apps accounting for the greatest number of subject-specific content (Shuler, 2012). This focus on mathematics applications may be because the proclaimed 'easy to use', 'accessible', and 'intuitive' aspects of these devices may offset the impression that mathematics is 'difficult', 'inaccessible', and 'unintuitive'.

The role that a touchscreen plays in the processing and understanding of content is, at this point, not well researched. Given our interests in learning theory and communications media, we employed concepts from cognitive psychology, information studies, and communication theory to explore whether users' physical interactions on a touchscreen device have consequences for their conceptual understanding of content – in this case mathematics.

1. Conceptual framework and background

1.1. Framing a study of touchscreens and mathematics

Information practice is a foundational concept in the field of

* Corresponding author. Learning Sciences, Department of Educational & Counselling Psychology, McGill University, 3700 Rue McTavish, Montreal, QC, H3A 1Y2, Canada.
E-mail address: Adam.Dube@mcgill.ca (A.K. Dubé).

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information studies that purports a relationship between the actions that users' engage in when sharing, seeking and using information, and the processing of that information through its use (Demmans Epp, McEwen, Campigotto, & Moffat, 2015; Savolainen, 2009). According to the information practice approach, observed actions can be understood as processes or strategies that users undertake when interacting with forms of information (Savolainen, 2009) – in this case, the gestures used during touchscreen interaction constitute a form of information practice. Furthermore, Luhmann (1992) provides a theoretical model where the exchanges that take place in user-device interactions can be viewed as a form of bi-directional communication. To adequately examine touchscreen learning, we must consider the extent to which the information practice of employing gestures in user-device communications enhances (or obscures) users' understanding of content.

Gestures not only constitute a form of information practice and communication, they are also a physical interaction. To understand the physical nature of gestures, we turn to cognitive science and embodied cognition theory. Embodied cognition, as applied within instructional design, purports an entangled relationship between thinking and acting (Spackman & Yanchar, 2013). As opposed to seeing an ontological separation between thought and action, embodied cognition theory maintains that these are intertwined in nature and that tangible engagement with objects affects the way we think about them and vice-versa (Black, 2010; Willems & Francken, 2012). Embodied cognition theory supports, in principle, the notion that touchscreens could lead to better knowledge search and learning because the theory suggests that binding knowledge with physical interactions improves knowledge acquisition, retention of information, and changes how the knowledge is conceptually understood (Wilson, 2002). Research has only recently begun to understand whether physical interaction is an important tool for learning mathematics (Alibali & Nathan, 2012). However, there is considerable research demonstrating that interacting with the physical world can generally augment one's internal mental representations (Goldin-Meadow & Beilock, 2010; James, 2010) and some recent research suggests that physical actions may improve children's early mathematics ability (Fischer & Brugger, 2011; Skwarchuk, Sowinski, & LeFevre, 2014). Given that touchscreen computers require physical interaction for knowledge acquisition to occur, the primary research question in this study is whether the physical interactions used while learning mathematics on a touchscreen device affect one's conceptual understanding of mathematics, or in other words, do gestures matter?

1.2. Background literature: 'Hands-on' mathematics and touchscreens

Touchscreens are lauded as providing a hands-on, interactive approach to learning that regular textbooks and oral instruction do not necessarily provide. However, mathematics is typically thought of as abstract with instruction focused on learning procedures and concepts that are generalizable (Rittle-Johnson, Siegler, & Alibali, 2001), and it is not clear whether or not hands-on experiences have consequences for mathematics learning. This is not to say that concrete examples play no role in making number concepts relatable. Counting physical objects and manipulatives (e.g., using pieces of a pie to teach fractions) are popular instructional tools and can improve children's mathematics understanding (Sherman & Bisanz, 2007). Yet, concrete instructional tools are often seen as a means to learning abstract concepts (Antle, 2013)—particularly in earlier developmental stages—and there is reason to believe that the use of concrete exemplars distracts learners away from the deeper conceptual structure underlying mathematics (Kaminski & Sloutsky, 2013). Still, the broader question of whether our understanding of mathematics is wedded to our interaction with the physical world is not generally asked. If hands-on interaction simply makes mathematics content more relatable then evaluations of touchscreen use in mathematics instruction should primarily concern whether the experience sufficiently instantiates the mathematics concepts. If hands-on interaction plays a more fundamental role in shaping our conceptual understanding of mathematics then the interaction with the device itself may be contributing to the foundation on which future mathematics learning is laid.

Recent research has demonstrated that early hands-on and informal interactions with numbers are important for children's later mathematics ability. Skwarchuk et al. (2014) asked parents of kindergarten-aged children about the frequency of their early formal and informal home numeracy practices to determine which of these practices were predictive of the children's symbolic and non-symbolic mathematics ability. Families' informal practices uniquely predicted non-symbolic arithmetic ability (i.e., simple addition and subtraction using concrete items) whereas formal practices uniquely predicted symbolic number knowledge (e.g., number identification and counting). Of particular interest to the current discussion is the difference between the formal and informal practices. Formal practices included abstract activities and discussions of number concepts (e.g., number recognition, discussing quantities, encouraging mental arithmetic, and practicing counting). In contrast, informal practices included hands-on activities in which physical number manipulations occurred but were not the focus of the interaction (e.g., number board games, measuring quantities while cooking). This result suggests that children's physical interactions with quantities improve their ability to mentally manipulate quantities later in life. These early physical interactions could be creating a schema—a blueprint or script used to guide behavior and thought based on the success of previous behaviors in similar scenarios (Spiro, 1980; Verschaffel, Luwel, Torbeyns, & Van Dooren, 2009)—for how later mental arithmetic is performed. Together, this could mean that mental arithmetic procedures are evaluated and adopted based on previous experience physically manipulating concrete quantities.

Research suggests that not only do early physical interactions with numbers predict later mathematics ability but that physical interactions can fundamentally alter, for both better and worse, one's conceptual understanding of mathematics. A series of studies have provided detailed information on how the physical manipulation of numbers in a simple number board game can shape children's early understanding of fundamental mathematic concepts (Ramani & Siegler, 2014). Ramani and Siegler (2008) had preschool children play a number board game in which a token is moved across a series of squares numbered from 1 to 10; children who played the game performed significantly better than children who played a similar game containing unnumbered items on measures of number line estimation (i.e., placing a number in its correct location on a line between two different numbers, e.g., placing 7 on a line between 1 and 10), magnitude comparison (i.e., quickly stating which of two numbers is larger), counting, and number identification—even after a 9 week delay in assessment. The sole physical interaction involved in the game was the movement of a token from a numbered square of lower numeric value to a numbered square of higher numeric value; the researchers proposed that the kinesthetic feedback provided by moving the token was combined with the process of counting up and that this combination was partially responsible for the improved performance on the mathematics measures.

The benefits of using kinesthetic feedback in counting make