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Haptic two-dimensional shape identification in children, adolescents, and young adults

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ABSTRACT

We investigated the influence of image mediation (the process that translates tactile information into a visual image) on the development of haptic two-dimensional (2D) shape identification in 78 participants from five different age groups: preschoolers (4–5 years), first graders (6–7 years), fifth graders (10–11 years), young adolescents (12–13 years), and young adults (18–28 years). Participants attempted to haptically recognize everyday objects (three-dimensional [3D] haptic condition) and tangible line drawings (2D haptic condition) and to recognize objects presented through a serial visual "peek hole" version of the haptic line drawing task (2D visual condition). All groups were excellent at 3D haptic identification. However, preschoolers and first graders scored low in both visual and haptic line drawing tasks. From fifth grade onward, participants were reliably better at the visual peek hole task compared with the haptic line drawing task, which improved only gradually in young adolescent and adult age groups. We argue that both the spatial reference frame and working memory capacity constrain image mediation and children's increasing abilities to correctly haptically identify 2D shapes.

Introduction

Children enjoy haptic shape identification as part of play, and their haptic sense is often believed to be fully developed at an early age. Drawing numbers or animals with a finger on the back of a partner,

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who must then recognize the shape, is a popular party pastime in preschoolers. Also in educational settings, learning by touch is considered to be more natural for children than vision. For example, object identification from two-dimensional (2D) shapes is an integrated teaching method in the Montessori tradition. However, empirical data supporting claims about children's haptic abilities are sparse and controversial. By studying 2D shape identification, we can isolate, and therefore investigate, specific haptic exploration strategies that involve high working memory load and the use of a spatial representation.

In a typical haptic 2D shape identification experiment, participants are asked to trace the lines of a tangible line drawing with their fingers by using the contour following exploratory procedure as characterized by Lederman and Klatzky (1987; see below). This task has been shown to be quite difficult for adults; identification rates are generally low even after extended exploration periods (Magee & Kennedy, 1980; Wijntjes, van Lienen, Verstijnen, & Kappers, 2008). Older adults in their 60 s and 70 s do even more poorly on 2D shape identification tasks than young adults, presumably because of age-specific constraints on visual mediation and working memory (Overvliet, Wagemans, & Krampe, 2013), even after extensive training (Overvliet, Krampe, & Krampe, in preparation).

Two recent studies investigated tactile capabilities in children from 5 to 18 years old and young adults in a variety of tasks (Mazella, Albaret, & Picard, 2016; Picard, Albaret, & Mazella, 2013). They found low performances on haptic 2D shape identification in young children and showed increasing performances with age. Similar to our earlier findings with older adults, here also performance was correlated to haptic working memory capacity. A question that remains is which other developmental processes constrain and promote these increases. The goal of our study was to map the developmental trajectory of 2D shape identification from early childhood to young adulthood. Specifically, we aimed to study the influence of image mediation on haptic 2D shape identification. To do so, we used the image mediation model (IMM) as a theoretical stepping stone for our study (Klatzky & Lederman, 1987; Lederman, Klatzky, Chataway, & Summers, 1990).

The IMM (Fig. 1; Klatzky & Lederman, 1987) aims to explain the processes underlying identification of haptic 2D shapes. According to the model, the low-resolution, temporally sequential haptic input that is gathered by the contour following procedure is translated into a visual image, which is then reperceived through the visual processors. Subsequently, the visual image is interpreted by matching it with long-term memory representations that would also contain the name of the object depicted by the shape. In a previous study, we investigated whether the IMM could account for adult age-related differences in the identification of haptic 2D shapes (Overvliet et al., 2013); older adults (>70 years) are slower and less accurate as compared with young adults (Kleinman & Brodzinsky, 1978). In that study, we tested young and older adults with different versions of haptic line drawing identification tasks, which allowed assessing the role of stimulus complexity, visual mediation, and working memory demands. Our results demonstrated that both image mediation processes and working memory demands were important factors in 2D shape identification and age-related performance declines in the elderly.

In the current study, we focused on the development of haptic 2D identification at the other end of the lifespan, namely childhood through adolescence to young adulthood covering the age range between 4 and 28 years. Most sensory and cognitive functions undergo massive developmental changes during that period, and very little is known to this point how these changes affect haptic 2D identification.

A few studies investigated 2D shape perception and production in children and in blind persons. For example, Picard, Lebaz, Jouffrais, and Monnier (2010) showed that sighted adults use visuospatial memory, whereas early and late blind persons use kinesthetic memory in haptic line drawing perception. Moreover, Heller, Calcaterra, Burson, and Tyler (1996) showed that visual experience has a significant impact on accuracy, with blind participants performing worse as compared with sighted ones. Thus, visuospatial memory seems to be an important factor in haptic 2D shape identification. Data on drawing capacities showed that children aged 7 years and older can draw integrated wholes (Nicholls & Kennedy, 1992; Toomela, 1999), whereas 2-year-olds draw only scribbles, 3-year-olds draw single units, and from 4 years of age children draw differentiated figures. Together, these results suggest a developmental trajectory for 2D shape *identification*, limited by the development of visuospatial memory.