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Brief article

The format of children's mental images: Evidence from mental scanning ☆

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ABSTRACT

This study examined the development and format of children's mental images. Children (4-, 5-, 6–7-, 8–9-, and 11-year-olds) and adults (*N* = 282) viewed a map of a fictitious island containing various landmarks and two misleading signposts, indicating that some equidistant landmarks were different distances apart. Five-year-olds already revealed the linear time-distance scanning effect, previously shown in adults (Experiments 1 and 2): They took longer to mentally scan their image of the island with longer distances between corresponding landmarks, indicating the depictive format of children's mental images. Unlike adults, their scanning times were not affected by misleading top-down distance information on the signposts until age 8 (Experiment 1) unless they were prompted to the difference from the outset (Experiment 2). Findings provide novel insights into the format of children's mental images in a mental scanning paradigm and show that children's mental images can be susceptible to top-down influences as are adults'.

1. Introduction

Mental imagery is ubiquitous in children's and adults' everyday life. The theoretical consensus over decades is that our mental images are depictive in format (*depictive theory*: Kosslyn, 1981; Kosslyn, Ganis, & Thompson, 2003). Apart from evidence from mental rotation (Estes, 1998; Frick, Daum, Walser, & Mast, 2009; Frick, Möhring, & Newcombe, 2014; Kosslyn, Margolis, Barrett, Goldknopf, & Daly, 1990; Marmor, 1975), there is limited research on the format of children's mental images. This research examines children's imagery format in mental scanning and how it is affected by knowledge.

Several studies have demonstrated that adults take longer to scan a mental image with more distant to-be-scanned-objects (e.g., Beech, 1979; Borst & Kosslyn, 2008, 2010; Borst, Kosslyn, & Denis, 2006; Finke & Pinker, 1983; Iachini & Ruggiero, 2010; Kosslyn, Ball, & Reiser, 1978). Specifically, adults mentally scan between landmarks on a previously presented island map in a time linear with landmarks' distances (Kosslyn et al., 1978). These findings demonstrate that mental images incorporate the metric information present in the original object or scene, indicating their depictive format (Denis & Carfantan, 1985; Denis & Kosslyn, 1999; Kosslyn et al., 2003).

Adults' performance on these tasks is penetrable by top-down influences such as verbal codes. Scanning times are influenced by misleading mileage signs indicating different distances between equidistant landmarks (Richman, Mitchell, & Reznick, 1979). Thus, mental scanning performance is cognitively penetrable by top-down factors, that is, the semantic content of participants' beliefs and goals (see Pylyshyn, 2003). The fact that 5-year-olds' visual perceptual processes are influenced by top-down processes (Doherty & Wimmer, 2005; Wimmer & Doherty, 2011) would suggest top-down influences on their mental imagery. To our knowledge this has not been examined to date.

Evidence of the depictive format of children's mental images comes mainly from mental rotation. Five- to 6-year-old children's response time, like adults', increases linearly with increasing rotation angle between objects (e.g., Estes, 1998; Frick et al., 2009, 2014). Moreover, 6-year-olds describe their mental rotation performance in mental state terms, whereas the minority of 4-year-olds does (Estes, 1998). That is, introspection into your own mental states allows mental rotation. This raises the possibility that introspective ability gives rise to knowledge penetrating mental images.

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Indeed, children's use of metacognitive strategies and insight undergoes significant developments between 4 and 8 years (Bjorklund & Douglas, 1997; Flavell, Green, & Flavell, 2000; Ghetti, Mirandola, Angelini, Cornoldi, & Ciaramelli, 2011; Perner, Kloo, & Rohwer, 2010; Schneider, 1986; but see Balcomb & Gerken, 2008; Call & Carpenter, 2001 for 2–3-year-olds showing already implicit monitoring abilities). Thus, one might expect top-down knowledge guiding imagery to be evident at 5 years.

To examine the format of children's and adults' mental images we adapted Kosslyn et al.'s (1978) "island task." Participants mentally scanned between landmarks of a previously presented island map image. Additionally, we examined how distance information on a map (top-down knowledge) affects its representation. For example, if one distance between landmarks is labelled as further away on a signpost (5 footsteps) than another (1 footstep), will it take children longer to mentally scan although the distances are the same (see Richman et al., 1979 for adult findings)? Do children show the typical time-distance linear relation (taking linearly longer to mentally scan between further apart to-be-scanned items), suggesting their mental images preserve metric distance. Additionally, we ask at what age children's mental images become penetrable to top-down information as adults. If children preserve metric distance in their mental images but their scanning is influenced by top-down factors then this strongly favours the idea that children's mental images are depictive in form while influenced by conceptual factors.

2. Experiment 1

2.1. Method

2.1.1. Participants

Overall 152 participants (76 females) participated: 24 4-year-olds (M = 60 months, range = 54–65), 26 5-year-olds (M = 71 months, range = 66–77), 26 6-year-olds (M = 83 months, range = 78–89), 25 8-year-olds (M = 107 months, range = 99–113), 25 11-year-olds (M = 132 months, range = 126–137) and 26 adults (M = 21 years, range = 19–31). In both experiments children were recruited from local schools and adults via the university sign-up system receiving financial reimbursement.

2.1.2. Materials and procedure

A map of a fictitious island (see Kosslyn et al., 1978; Richman et al., 1979) was presented on a standard 17.3 in. laptop screen, containing a Lighthouse, Volcano, Hut, Pond and Tree (Fig. 1). Two signposts pointed between the Lighthouse-Volcano and the Hut-Volcano (both of which were equal distances), adapted from the 20- and 80-mile ones used by Richman et al. (1979) to be suitable for 4–5-year-olds: one signpost showed 1 footstep and the number 1, the other 5 footsteps and the number 5. Sign post positions were counterbalanced between the two landmark pairs between participants.

Participants, tested individually, saw 'Percy the Pirate Parrot' walk across a map of a park. On 3 practise trials, participants closed their eyes and, on the experimenter's 'Start' command, imagined Percy walking between specified landmarks, and said 'Stop' when he had arrived at the second landmark. After each imagery attempt they watched Percy walking between said landmarks, were asked to compare this to how they imagined him walking, and given further instruction if necessary. In imagery trials participants viewed the island for 45 s. They named and memorised everything on it. After 45 s landmarks disappeared leaving an empty island. Participants used the mouse to drag and drop each landmark and the two signposts into their correct position on the island. Once a landmark was within a 30 pixel radius of its correct location it shifted and locked into place.

The island then disappeared. Participants closed their eyes and imagined the island with Percy standing at the Lighthouse and then walking between landmarks in the following order (actual distances in parentheses): Lighthouse-Tree (262 mm), Lighthouse-Volcano (81 mm), Lighthouse-Pond (154 mm), Lighthouse-Hut (70 mm), Hut-Lighthouse (70 mm), Hut-Pond (100 mm), Hut-Volcano (81 mm), Hut-Tree (260 mm). The computer recorded the time taken to mentally scan between each of the landmark pairs.

Finally, participants completed 'perception control' trials, where this process was repeated, but with the island visible on the screen. Participants were instructed to follow their eyes between the landmarks to imagine Percy walking between them. After the experiment participants were asked what the signs meant and which sign represented further.

2.2. Results and discussion Experiment 1

Across both experiments Bonferroni confidence interval adjustments and post hoc analyses were used. Outlier response times that were 2 standard deviations from the mean per distance and age group were removed.

2.2.1. Preliminary analyses

Whether the signposts pointed up or down had no effect. The four participants who were incorrect about the signposts' meaning were excluded from the signpost analysis.

2.2.2. Mental imagery scanning times over different distances

To control for any effects of the signposts on the time-distance linear relation, the two distances (both 81 mm) which had a signpost between each of them were excluded from this analysis.

Scanning times increased linearly with increasing distance for all age groups (all R^2s > 0.03, $ps < 0.05$) (Table 1).

However, for the 4-year-olds this relation was due to a large increase in scanning times between similar distances 260 mm (hut-tree) and 262 mm (lighthouse-tree), whilst there was no increase between other distances (Fig. 2). After removing scanning times for the 262 mm distance, 4-year-olds showed no time-distance linear relation. The model remained significant for all older age groups (all R^2s > 0.07, $ps < 0.005$).

To examine the trajectory of the time-distance-scanning relation across age, we calculated the slopes of the best fitting lines (i.e., scanning rates) for each participant, and then submitted these slopes to a one-way ANOVA. Slopes differed between age groups, $F(5,146) = 4.36$, $p < 0.001$, $\eta p^2 = 0.13$. Four-year-olds' slopes (B = 11.66 ms/mm) were less steep than 8- (B = 32.78 ms/mm), 11-year-olds' (B = 35.78 ms/mm) and adults' (B = 41.51 ms/mm) (all $ps < 0.05$). There were no further slope differences (5-year-olds: B = 26.97 ms/mm; 6-year-olds: B = 24.69 ms/mm, suggesting that the scanning time-distance linear relation did not change from age 5 onwards.

In perception control, all ages showed a linear time-distance relation (all R^2s > 0.08, Fs > 11.46, $ps < 0.001$).

2.2.3. Effect of signposts on scanning times

A 2 (sign: 1 vs. 5 footsteps) × 6 (age) mixed ANOVA revealed a main effect of sign, $F(1,142) = 4.51$, $p = 0.04$, $\eta p^2 = 0.03$. Participants showed longer scanning times for the 5 footsteps sign (M = 7841, SD = 4453) than the 1 footstep sign (M = 7265 ms, SD = 3959). There was no age effect, $F(5,142) = 1.08$, $p = 0.382$, $\eta p^2 = 0.04$, but a sign × age interaction, $F(5,142) = 2.40$, $p < 0.05$, $\eta p^2 = 0.08$. Only 8-, 11-year-olds and adults showed longer scanning times for the 5 footsteps sign than the 1 footstep sign, whilst