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Representational momentum in older adults

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ABSTRACT

Humans have a tendency to perceive motion even in static images that simply "imply" movement. This tendency is so strong that our memory for actions depicted in static images is distorted in the direction of implied motion – a phenomenon known as representational momentum (RM). In the present study, we created an RM display depicting a pattern of implied (clockwise) rotation of a rectangle. Young adults viewers' memory of the final position of the test rectangle was biased in the direction of continuing rotation, but older adults did not show a similar memory bias. We discuss several possible explanations for this group difference, but argue that the failure of older adults to shown an RM effect most likely reflects age-related changes in areas of the brain involved in processing real and implied motion.

1. Introduction

Humans have a tendency to perceive motion even in static images that simply "imply" movement. This tendency is so strong that our memory for actions depicted in such images is distorted in the direction of implied motion. Freyd (1983, 1987) was the first to demonstrate this effect, and coined the term representational momentum (RM) to describe the memory distortion. In a classic study (Freyd, 1983), she presented participants with a photograph depicting implied motion (e.g., a person about to jump off a wall), followed by a test photograph that depicted a moment earlier in time (i.e., backward discrimination) or a moment later in time (i.e., forward discrimination). Participants were asked to judge whether the test photograph was the same as, or different from, the original. Response times were longest in the forward discrimination condition. Freyd explained these results by suggesting that our mental representations of objects or scenes incorporate dynamic information and that, because of this, it becomes difficult for us to distinguish a photograph showing the continued action from the original.

RM effects have been described not only with stimuli that imply translation, but also with those that imply rotation. In one study, Freyd and Finke (1984) presented participants with a rectangle shown in three different orientations which suggested a clockwise rotational movement pattern. After the presentation of the last frame of this "inducing display" (the target), they presented a fourth (probe) rectangle. Participants were required to judge whether the probe was in the same or in a different orientation from the target. They were more likely to report that probes were in the same position as the target when they were rotated further along the path of implied rotation than when they were displaced backwards along that path.

Research has demonstrated that the RM effect can be influenced by numerous factors (see Hubbard, 2005, for a review). Some of these include the extent to which friction (Hubbard, 1995) and gravitational forces (Freyd, Pantzer, & Cheng, 1988; Hubbard, 1995) appear to be influencing an object's movement, and the object's (real or implied) velocity (Hubbard & Bharucha, 1988; Munger & Minchew, 2002). In the latter studies, the magnitude of the RM effect (i.e., the size of the memory bias) increased as (real or implied) velocity increased. The memory bias has also been found to be stronger with shorter interstimulus intervals (ISIs; 250 ms) than with longer ones (500 or 750 ms) (Freyd & Finke, 1984). This result suggests that there may be a slowing of the represented motion (a loss of "momentum") over time. This conclusion gains support from studies exploring a different, but related, skill – the ability to extrapolate the movement of an object that has disappeared from view, and predict when and where it will reappear (e.g., Cooper, 1989; Munger & Minchew).

The memory bias seen in RM studies utilizing static stimuli clearly suggests that human observers are readily able to extract motion that is simply implied. One question that arises is how this information is processed. The results of numerous functional imaging studies suggest that motion-sensitive cortical areas (such as the human MT complex and the superior temporal sulcus) and other, high-level visual processing areas are activated by static images that imply movement. These effects are seen in both humans (e.g., Kourtzi & Kanwisher, 2000a, 2000b; Krekelberg, Vatakis, & Kourtzi, 2005; Senior et al., 2000; Shulman et al., 1999)

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and macaque monkeys (Krekelberg, Dannenberg, Hoffmann, Bremmer, & Ross, 2003). Senior et al. (2000), for example, found that displays implying motion produced bilateral activation in the MT complex and in a more ventral and posterior region thought to be part of the ventral ("what") stream. The latter pattern of activation was only evident during perception of implied motion stimuli, and not during viewing of actual motion. The authors suggested that it might reflect retrieval of information about how the presented object would behave in the natural environment (i.e., visual semantic processing). This conclusion gains support from a visual evoked potential study demonstrating that response latencies to implied motion are longer than those seen with real motion – a result that might be expected if, in the former case, the object undergoing implied motion is processed in the higher-order temporal areas before undergoing additional processing in the MT complex (Lorteije et al., 2006).

Like Senior et al. (2000), Kourtzi and Kanwisher (2000a) suggested that in order to infer motion a person must first access object information, which occurs outside of the MT complex. They based this argument on functional imaging findings. In their first experiment, participants were presented with four different photographs: (a) an athlete in action; (b) an athlete at rest; (c) a person at rest; and (d) a house. The MT complex was found to be more active while participants viewed the athlete in action than while viewing a person (athlete or not) at rest; activation seen in these latter conditions, in turn, was more robust than that seen while participants viewed a house. In addition, however, stimuli that implied motion produced activation in regions medial, anterior, and posterior to the MT complex, including the superior temporal sulcus.

In light of the important role that motion-processing regions of the brain appear to play in the processing of implied motion, it is interesting to note that interrupting the activity of the MT complex through the application of transcranial magnetic stimulation eliminates the RM effect normally associated with viewing of frozen action photographs (Senior, Ward, & David, 2002). Given this, we might expect to see that the RM effect would be reduced or eliminated in individuals whose motion processing skills are either not fully mature, or impaired. Some support for this prediction comes from a recent study involving 5–9 year olds, showing that, in full-term children, age is positively correlated with the magnitude of the RM effect seen with stimuli undergoing implied rotation (Taylor & Jakobson, 2010). In contrast to this finding, however, some researchers have reported that the magnitude of the effect in children is either larger (Hubbard, Matzenbacher, & Davis, 1999) or comparable in size (Futterweit & Beilin, 1994) to that seen in adults. These inconsistencies might be explained by the use of different stimuli across studies, and by differences in the ages of the participants studied (cf. Hubbard, 2005; Taylor & Jakobson, 2010).

In other work, it has been reported that intellectually challenged adolescents show a memory bias that is smaller in magnitude than that seen in typically-developing, age-matched controls (Conners, Wyatt, & Dulaney, 1998). The dampening of the effect in this clinical group might reflect damage or dysfunction in cortical motion-processing areas, as other researchers have reported deficits in visual motion processing in such populations (Fox & Orass, 1990). This argument gains additional support from the finding that children who are born very prematurely show both impaired global motion perception and a weaker or absent RM effect compared with children who were born full-term (Taylor & Jakobson, 2010). These latter investigators proposed that white matter injury in the periventricular area at the junction of temporal, parietal, and occipital lobes may have contributed to difficulties with both tasks in the preterm population.

Impairments in visual motion processing are characteristic of normal aging (Gilmore, Wenk, Naylor, & Stuve, 1992; Habak & Faubert, 2000; Long & Crambert, 1990; Owsley, Sekuler, & Siemsen, 1983; Snowden & Kavanagh, 2006; Trick & Silverman, 1991) and likely reflect age-related changes in a number of brain regions, including cortical visual areas involved in motion processing (Blesa et al., 1996; Eberling et al., 1995; Moeller et al., 1996; Ohnishi, Matsuda, Tabira, Asada, & Uno, 2001; Petit-Touboué, Landeau, Desson, Desgranges, & Baron, 1998; Terry & Wisniewski, 1975). Given the proposed link between motion processing and the ability to represent motion in working memory, one might predict that older adults would show atypical RM effects, relative to those seen in young adults. To date, however, this prediction has not been directly tested. Some support for the idea that healthy aging is associated with changes in one's ability to represent dynamic information in memory does come, however, from several recent driving simulation studies examining older adults' motion extrapolation skills. In one such study (DeLucia & Mather, 2006), observers were shown simulated car-following scenes. At a given point in each trial, the scene was interrupted. When it reappeared, the scene represented either the correct (updated) position along the trajectory, or a position that was consistent with what would be seen either earlier or later in time. Drivers were asked to judge whether or not the scene reappeared at the correct position. Under certain conditions, older drivers' showed a bias to report that the earlier position was correct, while younger drivers showed the opposite effect. This result suggests that older drivers extrapolated the motion more slowly than younger drivers. Other evidence of age-related distortions in motion extrapolation skills comes from recent work by Anderson and colleagues (Andersen, Cisneros, Saidpour, & Atchley, 2000; Andersen & Enriquez, 2006).

Evidence suggesting that aging is associated with problems in representing dynamic information in working memory also comes from research into mental rotation. It has been reported by several authors that healthy aging is associated with a slowing of the rate of mental rotation (Cerella, Poon, & Forzard, 1981; Dror & Kosslyn, 1994; Gaylord & Marsh, 1975; Jacewicz & Hartley, 1987; Puglisi & Morrell, 1986). Interestingly, it has also been shown that mental rotation skills are more vulnerable to age-related decline than some other skills involving visual imagery (Dror & Kosslyn, 1994) – a finding that may reflect the vulnerability of areas of the brain involved in processing real and implied motion to age-related changes (see above). As slower mental rotation rates have been found to be associated with smaller RM effects in young adults (Munger, Solberg, & Horrocks, 1999), one might expect to find that older adults would show a smaller RM effect than younger adults. The purpose of the present study was to test this prediction.

Studies investigating older adults' ability to mentally extrapolate motion (e.g., DeLucia & Mather, 2006) have considered other variables that might affect task performance, including general problems related to working memory (Keys & White, 2000), cognitive slowing (Keys & White; Salthouse, 1982), and attention (Kline & Scialfa, 1997). In order to explore the possible impact of age-related declines in these skills on the magnitude of the RM effect, we measured participants' processing speed and their ability to maintain information about (static) symbols in working memory through administration of the Digit Symbol-Coding subtest of the Wechsler Adult Intelligence Test – III (WAIS-III, Wechsler, 1997). Attentional demands were kept constant across the various testing conditions. Measures of crystallized intelligence and verbal comprehension were included as additional control measures.

2. Method

2.1. Participants

Fourteen healthy adults (nine female, five male) over the age of 65 (M = 73.5 years, SD = 5.1) were recruited via announcements in