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Facilitating spatial perspective taking through animation: Evidence from an aptitude–treatment-interaction

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ABSTRACT

The present study examined the facilitating function of animations for spatial perspective taking. The task demanded to estimate directions to memorized objects in a spatial scene from an imagined position and orientation within the scene. Static pictures which required imagined reorientation of the self were compared to animations showing the reorientation externally. Individual differences in perspective taking ability were considered. Results showed a large effect in favor of animations for reaction times. An aptitude–treatment-interaction was found for accuracy: The relation between perspective taking ability and accuracy in direction estimation was moderated by type of presentation (static pictures vs. animation). Perspective taking ability played a much stronger role in direction estimation accuracy with static pictures than with animations. It is concluded that focused animations can facilitate perspective taking and thereby compensate for low spatial perspective taking ability.

1. Introduction

1.1. Animations for studying spatial configurations

Research investigating animations in learning has focused on the understanding of causal processes in domains such as biology, mechanical systems, or physics. Evidence for advantages of animated instruction compared to equivalent static images is inconclusive in those domains (e.g., Ayres & Paas, 2007; Betrancourt, 2005; Hegarty, Kriz, & Cate, 2003; Höffler & Leutner, 2007; Mayer, Hegarty, Mayer, & Campbell, 2005; Schnotz, Böckheler, & Grzondziel, 1999; Tversky, Morrison, & Betrancourt, 2002). However, in many domains (geography, virtual environments, anatomy, mechanical systems, chemistry, etc.), the understanding of the spatial configuration of the components of a system or the spatial relations between objects in a spatial scene is a learning goal per se. The popular use of animations and interactive software for 3D-visualizations of spatial configurations (e.g., interactive 3D-models of the anatomy of the human body, geographic information systems, virtual 3D-environments) suggests that those visualizations are considered supportive for spatial learning.

1.2. Perspective taking in studying spatial configurations

The present study examines the effect of animations for spatial perspective taking. Perspective taking means to imagine observing a spatial scene from another point of view, involving the imagination of an egocentric reorientation of the self. The spatial scene is interpreted with reference to the own body axes.

Static pictorial representations such as maps provide information about spatial relations between objects in an environment. These representations are typically studied with a particular orientation (e.g., maps are studied with north on top). Judgments of relative directions from memory are more difficult if they require reorientation, i.e., imagining another position and orientation than the orientation from which the representation has been studied. Mental representations of spatial configurations are thus thought to be orientation dependent (Levine, Jankovic, & Palij, 1982; Presson & Hazelrigg, 1984; Roskos-Ewoldsen, McNamara, Shelton, & Carr, 1998; Rossano & Moak, 1998; Rossano & Warren, 1989). The orientation specificity effect is also termed alignment effect. Alignment effects are considered robust (Presson, DeLange, & Hazelrigg, 1989; Presson & Hazelrigg, 1984). They occur both with large and small layouts (Roskos-Ewoldsen et al., 1998). The effect can be experienced in everyday spatial activities such as navigation. For instance, misaligned you-are-here maps impede orientation in a real environment (e.g., Klippel, Freksa, & Winter, 2006; Levine, 1982; Levine, Marchon, & Hanley, 1984; Montello, 2010).

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The alignment (or orientation specificity) effect that occurs with static pictorial representations shows that perspective taking is a challenging mental process that might benefit from appropriate visualization. With animations, the change of the viewpoint can be shown externally. Animations may thus facilitate perspective taking because the external presentation can support otherwise effortful mental visual–spatial processing (facilitation function, Schnotz & Rasch, 2005; supplantation, Salomon, 1994).

1.3. Spatial visualization ability and spatial orientation ability

Internal *spatial visualization* abilities – i.e., storing and manipulating mental visual–spatial representations (see Hegarty & Waller, 2005, for a review) – play an important role for spatial learning from external visualizations. For instance, in the domains of dental education and laparoscopic surgery, it has been shown that spatial abilities enhance learning and are also important for later performance (Hegarty, Keehner, Khooshabeh, & Montello, 2009; Keehner, Lippa, Montello, Tendick, & Hegarty, 2006; Rosenthal, Hamel, Oertli, Demartines, & Gantert, 2010).

It has been shown that successful spatial learning depends on spatial ability when learning with animations and interactive virtual environments (e.g., Cohen & Hegarty, 2007; Münzer & Stahl, 2011; Waller, 2000). A beneficial effect of animations for high-ability learners is termed “ability-as-enhancer” effect (Mayer & Sims, 1994). The effect implies that learning with animations depends on spatial ability, with higher spatial ability being associated with higher learning success. This implication is in conflict with a facilitation function of animations. If animations facilitate visual–spatial understanding, then learning success should be less dependent on spatial abilities (Münzer, Seufert, & Brünken, 2009).

A recent meta-analysis confirmed the important role of spatial abilities in multimedia learning (Höffler, 2010). Moreover, the meta-analysis supported the suggestions that animations can compensate for low spatial abilities. However, the meta-analysis focused on typical multimedia learning domains and did not include studies that considered spatial learning per se. The majority of the multimedia learning studies included in the meta-analysis utilized tests of *spatial visualization* and tests of *spatial relations* (following distinctions proposed by Carroll, 1993).

In the present study, individual differences in spatial perspective taking ability are considered. As noted above, perspective taking requires the imagined reorientation of the self. Such egocentric spatial transformations are thought to be associated with a visual–spatial ability factor termed *spatial orientation*. This factor is contrasted with the *spatial visualization* factor which involves the imagination of movements of objects and manipulation of objects while the egocentric viewpoint of the observer does not change (McGee, 1979). The distinction between *spatial visualization* and *spatial orientation* was called into question by later meta-analyses of factor-analytic studies (e.g., Carroll, 1993). However, recently the distinction was again supported with a new test of perspective taking (Hegarty & Waller, 2004; Kozhevnikov & Hegarty, 2001). This test requires participants to estimate relative directions between objects depicted on a map from different imagined positions and orientations. A dissociation between spatial visualization (object manipulation) ability and spatial orientation (perspective taking) ability was found (Kozhevnikov & Hegarty, 2001). Moreover, perspective taking ability was separable from mental rotation ability (Hegarty & Waller, 2004). In the present study, individual perspective taking ability is assessed with this test.

2. The present study

The experimental task required participants to form a mental representation of a spatial scene which comprised an indication of a person and two objects. Participants had to estimate the relative direction to one of the two objects from memory involving reorientation of the self (perspective taking) corresponding to the indicated position and orientation of the person. In the static presentation condition, perspective taking had to be mentally performed. In the animated presentation condition, the perspective taking process was shown externally.

The facilitation function of animations was investigated in the present study (1) with respect to task performance and (2) with respect to individual differences in perspective taking ability. First, it was predicted that animated perspective taking would facilitate direction estimation in the experimental task, compared to static pictures. Second, an aptitude–treatment-interaction (ATI) hypothesis was stated. The ATI hypothesis predicted that perspective taking ability would play an important role with static pictures (when internal processing of perspective taking was inevitable), but that perspective taking ability would not play an important role with animations (because the external visualization facilitated or supplanted internal perspective taking).

3. Method

3.1. Participants

Fifty-four students of Saarland University (27 females) took part in the study. Participants were, on average, 25.0 years old ($SD = 5.6$ years). They were paid for participation. Three participants were excluded because these participants missed more than two items of the perspective taking test. The remaining sample of 51 participants comprised 26 females and 25 males. For 19 participants out of 51 participants, reaction time data were not recorded due to a technical error.

3.2. Materials

3.2.1. Measurement of perspective taking ability

In the perspective taking test (Hegarty & Waller, 2004; Kozhevnikov & Hegarty, 2001), participants are asked to make directional judgments based on a map which shows a spatial configuration of seven objects (Fig. 1). Participants imagine themselves standing at a particular position (e.g., at the traffic light), facing a particular second location (e.g., the stop sign), and pointing to another location (e.g., the flower). The directional judgment is indicated by a position to be marked on the answer circle. The map is visible during answering. Participants process twelve items, all utilizing the same map. The score of the participant is the average angular error calculated from the items that the participant attempted to solve within the given time of 5 min. Reliability estimates between .79 and .85 (Cronbach's alpha statistic) are reported for this test (Hegarty & Waller, 2004). In the present study, seven participants out of 54 participants missed items of the perspective taking test. Two participants missed one item, two participants missed two items, and one participant missed four, five, and six items, respectively. All other participants completed all items. The three participants who missed more than two items were excluded from further analyses. In the present study, participants performed the perspective taking test with an average angular error of $M = 19.70°$, $SD = 11.81°$, $Min = 6.3°$, $Max = 64.6°$ ($N = 51$), closely resembling descriptive data reported by Hegarty and Waller (2004, Experiment 1) for this test. A significant gender difference was not found (females: $M = 21.09°$, $SD = 12.52°$; males: $M = 18.24°$, $SD = 11.08°$).

3.2.2. Experimental task and materials

Each item consisted of a virtual room shown on a computer screen which contained a blue and a red post and an indication of a person with a position and an orientation. The room was always shown from a bird's-eye view (Fig. 1). The angle difference in degrees between the bird's-eye view and the orientation of the indicated person was experimentally varied (50°, 90°, 130°, 170°). Eight items were prepared for each angle, both for static presentation and for animation. One of the two posts was the target post. The angles between the indicated person's position and orientation and the target post were varied over