Effects of observing and producing deictic gestures on memory and learning in different age groups

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Effecten van het observeren en produceren van deiktische gebaren op het geheugen en het leren in verschillende leeftijdsgroepen

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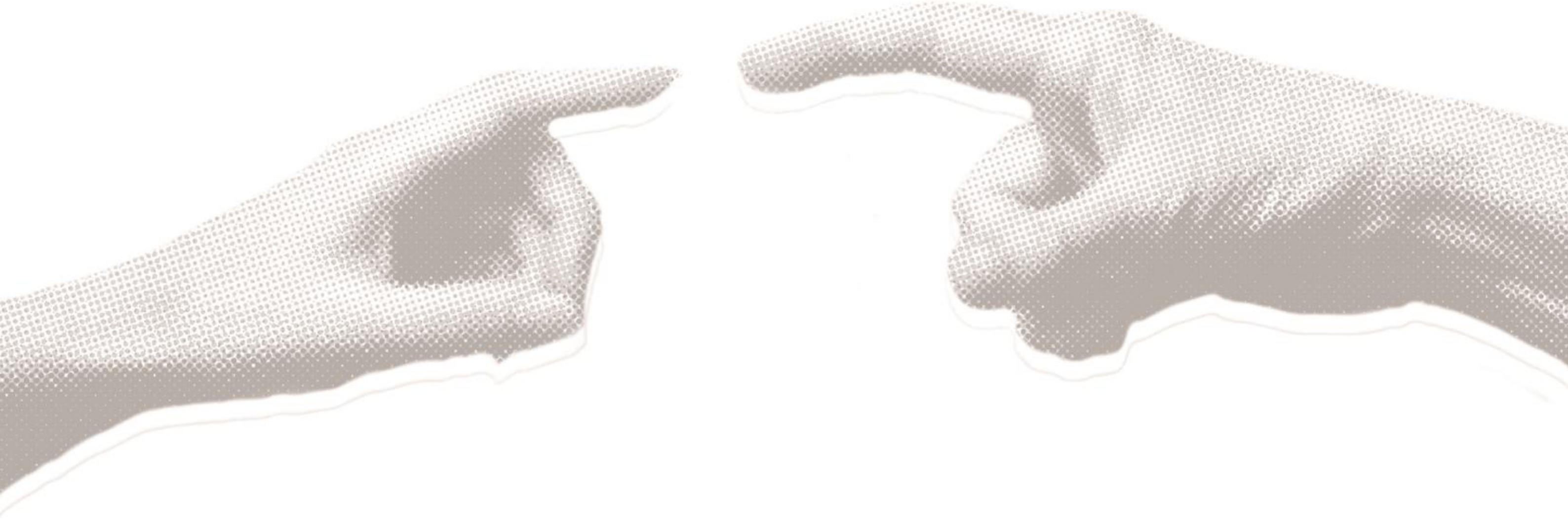
Chapter 1

General introduction



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Introduction

Given the fast technological developments, learning is nowadays not restricted to formal education anymore. In contrast, lifelong learning is stressed in our professional lives as well as in our personal lives. However, over the life course, cognitive abilities develop and change continuously. For example, working memory functioning improves during childhood and adolescence (Gathercole, Pickering, Ambridge, & Wearing, 2004) and declines when we get older (Celnik et al., 2006; Park et al., 2002). A similar pattern has also been found for source memory (e.g., Cycowicz, Friedman, Snodgrass, & Duff 2001; Old & Naveh-Benjamin, 2008; Ruffman, Rustin, Garnham, & Parkin, 2001) and cognitive control functions that are needed, for example, for selective attention (Gazzaley & Nobre, 2012) and interference control (Bunge, Dudukovic, Thomason, Vaidya, & Gabrieli, 2002; Houx, Jolles, & Vreeling, 1993; McDowd & Filion, 1995; Stolzfus, Hasher, Zacks, Ulivi, & Goldstein, 1993). As a consequence, it is important to consider these age-related differences in cognitive functioning when making instructional design choices for different age groups.

Cognitive load theory presents a perspective on learning and education that advocates taking human cognitive architecture, and particularly working memory limitations, into account in instructional design (Paas, Renkl, & Sweller, 2003; Sweller, 1988; Sweller, Ayres, & Kalyuga, 2011; Sweller, Van Merriënboer, & Paas, 1998). The design guidelines developed by cognitive load theorists are meant to optimize learning by reducing ineffective use of limited working memory resources, so that all available resources can be devoted to processes that are effective for learning (Paas & Van Gog, 2006; Sweller et al., 2011).

Recently, there has been growing interest in the role of the motor system in learning and memory from the perspectives of cognitive load theory (Paas & Sweller, 2012; Van Gog, Paas, Marcus, Ayres, & Sweller, 2009) and grounded cognition theory (for a review see, Barsalou, 2008). Cognitive load theory proponents suggest that the brain efficiently processes human movement (including gestures) because humans have evolved to do so (Paas & Sweller, 2012). Grounded cognition theorists propose that human cognition is grounded in sensory-motor experiences from interacting with the world (Barsalou, 2008). How the motor system facilitates learning according to these theorists will be discussed in more detail later in this chapter.

The studies presented in this dissertation aimed to investigate whether observing or producing deictic gestures (i.e., pointing and tracing gestures to index a referent in space or a movement pathway), would facilitate learning and memory in children, young adults, and older adults. More specifically, regarding memory it was investigated whether the use of deictic gestures would improve performance on tasks targeting cognitive functions that are found to change with age (working memory, cognitive control, and source memory). In addition, it was investigated whether the hypothesized improvements would be more pronounced for children in whom these cognitive functions are still developing, and for older adults, in whom these cognitive functions have been found to suffer from age-related declines.

Therefore, the main question addressed in this dissertation is whether the use of deictic gestures would improve learning as well as memory functions (such as source memory) that are known to change with age, and whether the degree of these improvements would be different for children, young adults, and older adults. In the remainder of this introductory chapter, relevant literature regarding age-related changes in cognition, cognitive load theory and instructional design, the role of the motor system in learning, and how gesturing may improve learning and memory in children, young adults, and older adults, is shortly described.

Age and cognition

Some important cognitive functions required for memory and learning change across the life span. The cognitive functions of interest in this dissertation, being working memory, cognitive control, and source memory, seem to follow an inverted U-shape as a function of age. This means that in children these functions are immature and develop until young adulthood, after which they decline from adulthood to old adulthood (Bedard et al., 2002; Borella, Carretti, & De Beni, 2008; Bunge & Wright, 2007; Gathercole et al., 2004; Shing et al., 2010).

Working memory as defined by Baddeley (2000), is a “limited capacity system allowing the temporary storage and manipulation of information necessary for such complex tasks as comprehension, learning and reasoning” (p. 418). Within working memory, a distinction can be made between active and passive working memory processes (Vecchi, Richardson, & Cavallini, 2005). Passive working memory functions involve the passive storage of information and recall of this information in the format in which it was presented, while active working memory functions involve more active processes, needed to be able to mentally transform, integrate, or manipulate information (Vecchi et al., 2005). Active working memory requires a higher degree of cognitive control than passive working memory. Cognitive control can be described as an internal mechanism, orchestrating all kinds of higher order cognitive processes, such as working memory, inhibition, attention, executive functioning, episodic memory, and prospective memory (Braver & Barch, 2002). Children (Crone, Wendelken, Donohue, Van Lijenhorst, & Bunge, 2006) and older adults (Vecchi et al., 2005) have more problems with tasks requiring active working memory than young adults. Evidence suggests that age-related differences in passive working memory functioning are smaller compared with differences in active working memory functioning (Crone et al., 2006; Vecchi et al., 2005). These findings suggest that active working memory relies more heavily on the cognitive control system (that functions suboptimally in children and older adults) than passive working memory.

Episodic memory is also sensitive to age in that children (Cycowicz et al., 2001; Ruffman et al., 2001) and older adults (Old & Naveh-Benjamin, 2008) have more problems with memory for associations, also called source memory, than with memory for single items, also called item memory. Source memory involves the formation of associations between different elements of an event (Mangels & Heinberg, 2006). Source memory supports learning and binding of several aspects of learning materials: perceptual (i.e., visual, and/or auditory instructions), conceptual (i.e., semantics of the learning materials), spatial (i.e., location of presented information elements) and temporal aspects (i.e., order in which the information is presented). Although research has shown that children perform less well on source and item memory tasks than young adults, this age-related difference is larger for source memory (Cycowicz et al., 2001; Sprondel, Kipp, & Mecklinger, 2011). In addition, developmental studies have shown a larger improvement of source memory performance than item memory performance from childhood (7-8 years) to adolescence (13-14 years) (Sprondel et al., 2011) and from childhood (7-9 years) to young adulthood (18-24 years) (Cycowicz et al., 2001). Chalfonte and Johnson (1996) found that older adults performed as well as young adults on an item memory task in which they had to remember colors and objects in isolation, but worse when they were asked to remember the color of an object, that is, when they had to bind color and object. Another study by Kessels, Hobbel, and Postma (2007) showed that older adults had more problems overall with memory for ‘where’ (spatial associations) and ‘when’ (temporal associations) a certain target was presented, compared with the recollection ‘that’ a specific target was presented. This dichotomy between memory for separate items and associations between items and contextual information (i.e., spatial, temporal) implies that there are different mechanisms underlying memory for associations and item memory.

These findings are explained by evidence showing that the development of source memory is associated with the development of the frontal lobes (e.g., Dobbins, Foley, Schacter, & Wagner, 2002; Trott, Friedman, Ritter, Fabiani, & Snodgrass, 1999), brain areas that do not fully mature until young adulthood (Sowell, Thompson, Holmes, Jernigan, & Toga, 1999) and deteriorates in old adulthood (West, 1996). A study comparing young and older adults’ source memory performance indeed found that source memory performance was related to frontal lobe functioning (Glisky, Rubin, & Davidson, 2001). Consistent with this idea, Naveh-Benjamin (2000) has proposed the associative deficit hypothesis in explaining the deficits in source memory in older adults. According to this hypothesis the relatively impaired memory for associations is a dominant factor in the age-related deficits of source memory functioning. The associative deficit hypothesis has received support from several experiments using different kinds of stimuli, such as word-non-word pairs, word-word pairs, and words presented in different font (Naveh-Benjamin, 2000), name-face pairs (Naveh-Benjamin, Guez, Kilb, & Reedy, 2004), picture pairs (Naveh-Benjamin, Hussain, Guez, & Bar-On, 2003), and face-spatial location pairs (Bastin & Van der Linden, 2005). More generally, the impaired associative memory can be regarded as a difficulty to bind or integrate information elements into complex memories (Chalfonte & Johnson, 1996).

In sum, some important cognitive functions for learning change across the life span, and this should be taken into account in instructional design for educational materials to be effective at different ages. An important line of research that advocates such a cognitive ergonomic approach is pursued in the context of cognitive load theory (Paas et al., 2003; Sweller et al., 1998; Sweller et al., 2011).

Cognitive load theory

The central tenet of cognitive load theory is that learning can be seriously inhibited if the capacity and duration limitations of working memory are not taken into account in the design of instruction (Sweller, 2010). In short, cognitive load theory distinguishes among three kinds of cognitive load in relation to learning: 1) intrinsic load, which is a property of the study material in interaction with the pre-existing knowledge of the learner, 2) extraneous load, which is imposed by the instructional design, that is, the presentation of the learning material, and 3) germane cognitive load, which reflects the amount of cognitive resources that are needed to deal with the intrinsic load (for a review see, Paas, et al., 2003).

According to cognitive load theory, schema construction and automation are the most important processes in learning. Schemata are stored in long-term memory and can be regarded as mental models in which all pieces of information, also called information elements, are categorized and organized (Sweller et al., 1998; Van Merriënboer & Sweller, 2005). The number of relations between information elements in a learning task together with the pre-existing knowledge of the learner determines the degree of element interactivity in that task, which is the main determinant of intrinsic load imposed by the task (Sweller, 2010; Sweller & Chandler, 1994; Tindall-Ford, Chandler, & Sweller, 1997). Learning materials with low element interactivity have a low intrinsic load because individual elements can be learned with minimal reference to other elements and therefore, impose a low demand on working memory. In contrast, in materials with high element interactivity, individual elements heavily interact and therefore cannot be learned in isolation. For successful learning of materials with high element interactivity, multiple elements need to be associated and integrated into the schema (Sweller et al., 1998). Although schemata are stored in long-term memory, the construction of such schemata is an active process that takes place in working memory. Existing schemata can be regarded as sophisticated rules that can be applied and eventually (after extensive practice) used automatically (Sweller et al., 1998). According to cognitive load theory, to design effective instruction for complex cognitive tasks (high in intrinsic load), extraneous load should be reduced and germane load should be optimized, so that the limited working memory capacity can be allocated as much as possible to schema construction and automation processes.

Instructional guidelines from a cognitive load theory perspective

Novices usually experience high cognitive load when learning complex tasks or materials, because they do not yet possess the appropriate (partial) schemata to guide their task performance or learning process. Several instructional design guidelines have been identified in cognitive load theory research that can support novices' learning by optimizing their working memory load, such as *provide worked examples* (for a review see, Renkl, 2014; Van Gog & Rummel, 2010), *avoid split attention* (for a review see, Sweller et al., 2011), *offer information in multiple modalities* (for a meta-analysis see Ginns, 2005), and *provide cues or signals* to guide attention to important information (for a review see, De Koning, Tabbers, Rikers, & Paas, 2009; Van Gog, 2014).

The 'worked example effect' is the term used to refer to the superior learning from worked examples that demonstrate how to solve a problem by showing learners a fully worked-out solution procedure compared with conventional problems that learners have to solve without any assistance (Sweller & Cooper, 1985) and this effect has been found in numerous studies (e.g., Atkinson, Derry, Renkl, & Wortham, 2000; Renkl, 2014; Van Gog & Rummel, 2010). Worked example study improves learning compared with problem solving because problem solving requires considering alternative problem states and moves, which is very demanding for working memory but contributes little to learning in novices. Because novices lack prior knowledge of effective strategies, they have to resort to ineffective strategies for selecting moves. This load that these ineffective strategies impose is prevented in worked examples, in which the solutions are already worked-out. This frees up working memory resources that can be dedicated to studying the procedure and constructing a schema of how the problem should be solved, that can guide future attempts to solve similar problems (Sweller et al., 2011).

The 'split-attention effect' reflects the finding that for complex tasks with high element interactivity, an instructional format that presents the study material in an integrated manner, improves learning compared with a format in which learners have to integrate information elements themselves (Sweller et al., 2011). For example, learning from worked examples consisting of a diagram and text, is improved when the text is presented in the diagram in such a way that the solution steps are presented in close physical proximity to the part of the diagram they refer to, compared with when the picture is presented above, below or next to the text (e.g., Sweller, Chandler, Tierney, & Cooper, 1990). This can be explained by the fact that an integrative instructional format prevents the extraneous load that is imposed by the need to mentally integrate relations between information elements in segregated instructions. This frees up working memory resources that can be dedicated to dealing with the intrinsic load of the material (Sweller, 2010). Mayer and Moreno (2003) distinguish between temporal and spatial contiguity, which both relate to split attention in multimedia learning. Spatial contiguity refers to presenting mutually referring information sources in spatial proximity (cf. the integrated format just discussed), while temporal contiguity refers to presenting information in close temporal proximity. An instructional format that is very suitable for application of the temporal proximity principle (Mayer, 2001) is a multimodal format in which information is simultaneously presented to different sensory modalities, for example, with speech and gestures.

Research inspired by cognitive load theory has shown that multimodal instruction can improve learning compared with unimodal instruction in which the information is presented to only one modality (i.e., the modality effect; for a meta-analysis see Ginns, 2005; Low & Sweller, 2005). Instructions using combinations of visual and auditory information presentation have been found to increase young (Mousavi, Low, & Sweller, 1995; Tindall-Ford et al., 1997) and older adults' learning efficiency (i.e., equal/higher performance attained with lower/equal mental effort investment; Paas & Van Merriënboer, 1993; Van Gerven, Paas, Van Merriënboer, & Schmidt, 2002). For instance, example-based learning was improved by using a multimodal compared with a unimodal format of instruction (e.g., Mousavi et al., 1995; Tindall-Ford et al., 1997). Mousavi et al. (1995) showed that problem-solving performance after studying worked examples in geometry, was improved when worked examples were presented as pictures and spoken text (multimodal: visual and auditory) compared with pictures and written text (unimodal: visual only). This finding was replicated by Tindall-Ford et al. (1997), who used worked examples about electricity and also showed that the multimodal instruction was only more beneficial for learning than unimodal instruction for high element interactivity learning materials. For instructions with high element interactivity, a multimodal format of instruction can reduce cognitive load by reducing visual search processes, information integration processes, and by distributing the load over different working memory stores (Van Gerven et al., 2002). Baddeley's (1992) model of working memory is used to explain this 'modality effect'. According to this model working memory consists of a control system (the central executive) and two partly independent slave systems one for visual information (the visuospatial sketch pad) and one for auditory information (the phonological loop). Cognitive load theory proposes that multimodal information presentation enhances learning because the limited capacity of working memory can be more efficiently used when the presentation of the learning material is divided over the two partly independent slave systems (Ginns, 2005).

Using gestures in a multimodal instruction

In addition to the visual and auditory modality, research has shown that adding information to the motoric modality in the form of gestures (either observed or self-produced) can facilitate learning and reduce cognitive load (Cook, Mitchell, & Goldin-Meadow, 2008; De Koning & Tabbers, 2013; Goldin-Meadow, Nusbaum, Kelly, & Wagner, 2001; Goldin-Meadow & Wagner, 2005; Hu, Ginns, & Bobis 2015; Valenzeno, Alibali, & Klatzky, 2003). Besides having a motoric component, gestures are also visible and therefore bimodal in nature, and because they are easily combined with speech (auditory modality) and/or other visual information, they fit well in multimodal instructions.

However, gesturing might not benefit all learning. In line with what cognitive load theory would predict, tasks should have a level of complexity in which the reduction of extraneous cognitive load would be necessary to improve performance. This claim is supported by a study by McNeill, Alibali, and Evans (2000) in which children got a description of a picture, either verbally or verbally with a corresponding gesture. However, the verbal description was easy or difficult to understand in terms of how many pieces of information it contained and syntactic complexity. It was found that gestures only improved task performance when they accompanied a complex verbal description. That gestures can lighten cognitive load, has been demonstrated in several studies (Goldin-Meadow et al., 2001; Ping & Goldin-Meadow, 2010). Using a dual-task paradigm for cognitive load measurement (for a review, see Brunken, Plass, & Leutner, 2003), Goldin-Meadow et al. (2001) asked participants to solve a math problem, after which they were presented with a list of words they had to remember while verbally explaining how they came to their solution. Half of the participants were permitted to gesture, whereas the other half were not. The main finding was that participants who were allowed to gesture, remembered more words from the word list compared with those who were not. This finding suggests that gestures lower the working memory load imposed by explaining the solution procedure (i.e., the primary task), leaving more resources available that could be successfully dedicated to remembering the word list (i.e., the secondary task).

Another study found that requesting children to produce gestures during learning about mathematical equations enhanced the retention of the learned material relative to when they were not requested to gesture (Cook et al., 2008). Furthermore, a series of experiments of Chu and Kita (2011) showed that gestures enhanced learning of spatial problem-solving tasks and were especially used when task complexity was high. They found that participants produced more spontaneous gestures when they found it difficult to solve the problems. Moreover, participants who were encouraged to gesture solved more problems in a mental rotation task, compared with participants who were prohibited from gesturing. Also, gesture rates in the first group decreased as they solved more problems. According to the researchers, gesture production decreased with increasing experience with the task because the spatial computation processes initially supported by gestures, become internalized; or, in cognitive load theory terms, because the intrinsic load imposed by the task decreases with increasing expertise, the reduction of cognitive load through gestures is no longer needed to support learning. In line with cognitive load theory, these findings suggest that gestures are especially beneficial for learning when cognitive load is high, such as in comprehending a difficult verbal description of pictorial information (McNeill et al., 2000), during dual task performance (Goldin-Meadow et al., 2001), or when solving novel problems (Chu & Kita, 2011).

The studies in this dissertation investigate the assumption that deictic (i.e., pointing and tracing) gestures could be a useful instructional tool because they can help to reduce cognitive load via the mechanisms described earlier (i.e., split-attention effect, cueing effect and modality effect). For example, an instructor's pointing might help avoid negative effects of split attention by guiding the learners' attention toward relevant corresponding areas in the text and picture (cueing effect). This can reduce the need for visual search, and prevent interference of irrelevant information, which frees up resources that can be dedicated to learning.

Indeed, recent evidence indicates that students who are instructed to produce deictic gestures (point and trace with the index finger) toward important parts of information in worked examples on geometry rules, outperform those who do not gesture; they perform better on subsequent tests, show shorter time on task and experience the test questions as less difficult (Hu et al., 2015). Besides a possible split-attention effect and cueing effect, these results can also be explained by a modality effect in that adding a motoric and tactile modality to the visually presented worked examples led to more efficient learning. To activate the motor modality, overt action is not always necessary (the reason why is explained in the section "The role of the motor system in learning" below); action observation can also be effective. A study by De Koning and Tabbers (2013) showed that gesture observation enhanced learning about the formation of lightning. Participants had to learn from an instructional animation, in which relevant areas were either cued by a moving arrow that participants had to observe or follow with their index finger (self-gesturing), or by a (picture of a) human hand moving in the same manner as the arrow in the other condition. Results showed superior learning from the animation in which participants observed the gesture cue, compared with observing the arrow cue or self-gesturing. In addition, Buisine and Martin (2007) showed that deictic gestures can help learners integrate initially separate information elements. Participants learned from an animation about the functions of a remote control. The animations consisted of a simultaneous presentation of a picture of the remote control and an animated agent explaining the button functions with or without deictic gestures. There were two gesture conditions, one in which the gesture conveyed the same information as the verbal explanation (i.e., saying "You have to use the large button in the center to…" while simultaneously pointing at this button) and one in which the information of the gesture that was complementary to its verbal explanation (i.e., "You have to use this button to…" while simultaneously pointing at the large button in the center). It was found that participants who saw the agent make gestures that conveyed the same information as the speech, recalled more verbal information, and gave higher ratings about the quality of the instruction. Results of this study show that the pointing gestures of the animated agent enriched the verbal information about the function of the button with a 'bodily' visuospatial representation of the location of that button in an integrated manner and that this enhanced learning. In addition, Mayer and DaPra (2012), also showed that students' transfer performance is improved when learning about electricity from an animated agent with a high level of embodiment that is, using human-like gesture, facial expression, eye gaze and movement.

To explain the mechanisms underlying multimodality effects, it is important to know how the brain deals with multimodal information, which will be described in the following section.

Multimodal information processing in the brain

Although the studies in this dissertation do not involve neuroscience techniques, knowledge of how multimodal integration takes place at a neural level can help understand the mechanisms underlying the 'modality effect' described earlier. Several researchers have identified a specific brain area that is often associated with multimodal integration, namely the superior temporal sulcus (STS; Beauchamp, Argall, Bodurka, Duyn, & Martin, 2004; Beauchamp, Lee, Argall, & Martin, 2004). In the STS, neurons are identified that respond to auditory or visual stimuli in isolation but also a specific set of neurons that are especially sensitive to multimodal stimulation (visual and auditory), as reflected by a response that surpasses the sum of activations elicited by visual or auditory stimuli in isolation (Beauchamp et al., 2004). This may explain behavioral findings showing that visual and verbal information corresponding to the same object can have additive effects on memory (Clark & Paivio, 1991). As mentioned above, research on the modality effect inspired by cognitive load theory, has also shown that learning more complex tasks is improved from using multiple modalities (Tindall-Ford et al., 1997).

Interestingly, there is also evidence for such multimodal enhancement resulting from gesturing. Holle, Obleser, Rueschemeyer, and Gunter, (2010) found a similar enhanced response to multimodal speech-gesture stimuli in the superior temporal areas of the brain, that were identified by Beauchamp et al. (2004) as integration areas for multimodal stimuli. In support of the multimodal enhancement theory, Holle et al. (2010) suggested that gestures boost speech comprehension under adverse listening conditions, with a crucial role for the left superior temporal areas in this process. This was confirmed by behavioral measures showing that participants understood significantly more under the speech-gesture condition compared with the speech only condition. When a gesture accompanied an action phrase that was hard to comprehend, participants understood 57 % of all stimuli, but without a gesture, they only understood 25%. These findings suggest that the human brain deals quite efficiently with information presented in a multimodal format, using the auditory, visual, and motoric (gesture) modality. This could explain findings from educational research, where multimodal instructions with gestures have been found to have positive effects on learning (Buisine & Martin, 2007; De Koning & Tabbers, 2013; Hu et al., 2015; Mayer & Da Pra, 2012) and implicates an important role of the motor system in learning.

Two theories that emphasize the role of the motor system in learning, memory and cognition more generally are cognitive load theory (Paas & Sweller, 2012) and the embodied or grounded cognition perspective (Wilson, 2002).

The role of the motor system in learning

From a cognitive load theory–perspective, Paas and Sweller (2012) elaborated on the evolutionary educational psychology view of Geary (2008, 2012) who distinguished between two types of information, namely biologically primary information and biologically secondary information. Biologically primary information is information that the human brain has evolved to learn automatically, for example, the ability to speak a mother tongue and the ability to recognize faces and human movement. Biologically secondary information is information that has to be explicitly taught. This is information that is valued in a certain culture or group, such as writing and mathematics. Because learning biologically primary information is a more automatic process, this is less restrained by the limitations of working memory than learning biologically secondary information (Paas & Sweller, 2012). Therefore, Paas and Sweller propose that the use of biologically primary information might enhance the learning of biologically secondary information. An important example of biologically primary information is the ability to automatically process perceptual information about human movement by using our own body-based knowledge. Cognitive load theory proposes that using such primary information in instruction can enhance learning about biologically secondary information (for example, if a teacher uses gestures when explaining about a geometry problem). A possible mechanism via which this occurs, comes from evidence showing overlapping activation in a specific set of neurons (i.e., mirror neurons) when observing and performing a certain human movement (Rizzolatti & Craighero 2004). It has been proposed that observing human movements automatically activates the mirror neuron system, which plays an important role in observational learning, action recognition, and intention understanding (Iacoboni et al., 2005). It has also been suggested that the mirror neuron system might play an important role in learning from computer-based dynamic visualizations (e.g., animations, videos) that incorporate human movement (Van Gog et al., 2009). Dynamic visualizations about non-human movement procedures or processes (e.g., demonstrating cell division, how lightning develops, how brakes or engines work) are often less effective for learning than a series of static visualizations, because of the high perceptual and cognitive load imposed by transience of information in the dynamic visualizations (Ayres & Paas, 2007). However, this is not the case for dynamic visualizations about procedures involving human movement (Höffler & Leutner, 2007; Van Gog et al., 2009; Wong et al., 2009). Van Gog et al. (2009) propose that the high load imposed by transience is not a problem in dynamic visualizations on human movement procedures due to the automatic processing in the mirror neuron system of (part of) the information.

Another view that emphasizes the role of the motor system (together with the perceptual system) in cognition is the theory of grounded cognition (for a review, see Barsalou, 2008), which states that human cognition is grounded in sensorimotor interactions rather than abstract symbols (Dijkstra & Zwaan, 2015). Thus our understanding of the world is based on perceptual and motoric interactions with our environment and previous perceptual and bodily experiences shape our cognition (for a review, see Barsalou, 2008). For example, imagining an object (e.g., a kite) seems to elicit similar brain activation patterns as actually seeing that object (Ganis, Thompson, & Kosslyn, 2004), and as mentioned above, imagining an action or seeing someone else perform that action seems to elicit similar brain activation patterns as actually performing that action (Rizzolatti & Craighero, 2004). Simulations are multimodal; apart from the visual modality, they contain relevant motor and mental states that were part of the original experience (Dijkstra & Zwaan, 2015). For example, thinking of or seeing a picture of a flying kite might be associated with the motor response of “looking up”. Because such mental simulations are activated automatically (Barsalou, 2008), perception and memory may be influenced by pre-existing knowledge and earlier experiences without extra effort or even conscious awareness.

Both cognitive load theory and grounded cognition theories suggest that the human brain processes human movement very efficiently. Because humans seem to automatically and quite effortlessly process perceptual information about human movement by using their body-based knowledge of moving their own body (as illustrated by the automatic activation of the mirror neuron system during action observation; Rizzolatti & Craighero 2004), the processing of human movement can be seen as biologically primary information. From this it can be hypothesized that including human movement in instruction facilitates learning biologically secondary knowledge. Note that this is in line with research (described earlier) finding positive effects of deictic gestures in instruction on learning about the formation of lightning (De Koning & Tabbers, 2013), geometry rules (Hu et al., 2015), and electricity (Mayer & DaPra, 2012). Because the processing of biologically primary information requires less working memory capacity, using gestures in instruction can be especially helpful for learning and memory performance in populations with suboptimal working memory such as children (Gathercole et al., 2004) and older adults (Celnik et al., 2006; Park et al., 2002).

How can gestures enhance learning and memory in different age groups?

As mentioned earlier, performance on tasks targeting working memory (Celnik et al., 2006; Gathercole et al., 2004; Park et al., 2002), cognitive control (Bunge et al., 2002; Houx et al., 1993; McDown & Filion, 1995; Stolzfus et al., 1993), and source memory (e.g., Cycowicz et al., 2001; Old & Naveh-Benjamin, 2008; Ruffman et al., 2001) is suboptimal in children and older adults, compared with young adults. In terms of cognitive speed, children (Fry & Hale, 2000) and older adults (Salthouse, 1996, 2000) are slower than young adults on all kinds of cognitive tasks. From the evidence described above, gestures seem to be a promising tool to enhance learning and memory because gestures might compensate for these age-related declines in cognitive functioning.

First, with regard to the age-related working memory impairments, dual task research has shown that gestures reduce cognitive load directly (Goldin-Meadow et al., 2001). Indirect evidence that gestures seem to offload working memory, comes from studies showing that gesturing is especially helpful (McNeill et al., 2000) and more used (Chu & Kita, 2011) in performing complex tasks for which working memory load is expected to be high compared with simple tasks for which working memory load is expected to be low. Second, with regard to the age-related impairments in cognitive control functions, research inspired by cognitive load theory has shown that gestures can serve as attentional cues (De Koning & Tabbers, 2013), thereby avoiding split attention and decreasing the need for cognitive control functions guiding visual search, selection and interference control. Third, with regard to the age-related source memory impairments, evidence showed that deictic gestures can have an integrative function by linking initially separate information elements (Buisine & Martin, 2007).

In sum, gestures have been found to enhance learning and memory in different age groups and different tasks. However, the effectiveness of gesturing for memory and learning has not yet been compared between these three different age groups, and especially research on elderly is scarce. The studies in this dissertation aimed to investigate the effect of deictic gestures in tasks targeting learning and memory functions that are known to change with age. Two main research questions are addressed in this dissertation. First, does observation or production of deictic gestures enhance learning and memory functions that are known to change with age? Second, are the (hypothesized) effects of gesture observation and production stronger in children and older adults (whose memory functions are still developing or already declining, respectively) than in young adults?

Overview of the studies in this dissertation

This dissertation can be roughly categorized in two parts. The first part of this dissertation presents studies investigating the effect of observing deictic gestures made by a human model during instruction of a problem-solving task on children's, young adults' and older adults' learning (**Chapter 2**) and young adults' visual attention (**Chapter 3**). The second part presents studies investigating the effects of self-performed deictic gestures during encoding on spatial source memory in young and older adults (**Chapter 4**) and in children and young adults (**Chapter 5**), as well as on spatial working memory in young and older adults (**Chapter 6**).

Part 1

Chapter 2 presents three experiments that investigated children's, young adults' and older adults' learning of a novel problem-solving task from observing a video-based modeling example in which an instructor (the model) demonstrated and explained how to solve the problem. The video example was based on a typical modern lecture setting, in which the model stood next to a whiteboard on which the task was displayed. The task used was a computerized version of Luchins' (1942) water jug task (Schmid, Wirth, & Polkehn, 2003). The female model explained the task and depending on the instructional condition, she verbally referred to the task while: (i) making head movements toward the screen (no cue condition – although note that the gaze might have provided a less specific kind of cue, cf. Chapter 3), or in addition to those head movements, either (ii) an artificial cue indicated the area of the task that the model referred to on the screen (arrow cue condition), or (iii) she made pointing and tracing gestures to the area(s) she referred to on the screen (gesture cue condition).

First, it was hypothesized that the gesture cue condition would lead to better learning efficiency (reflected in higher performance, lower mental effort and shorter time on task) than the arrow cue condition or no cue condition. Because gestures especially seem to aid learning in complex tasks, that is, if cognitive load is high (Chu & Kita, 2011; Goldin-Meadow et al., 2001; McNeill, et al., 2000), two levels of task complexity (lower and higher) were included. However, because children and older adults have suboptimal functioning of some cognitive properties important for learning novel problem-solving tasks, such as working memory and cognitive control (Crone et al., 2006; Vecchi et al., 2005), tasks at both complexity levels were expected to be more difficult for these groups than for young adults. Thus besides an effect of task complexity within groups, also a between group effect was expected in that young adults would outperform children and older adults. Finally, because task complexity would be relatively higher for children and older adults compared with young adults, possible learning gains were also expected to be higher in these groups than in young adults (i.e., the effects of gestures would be larger).

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Chapter 3 presents an experiment that investigated whether the gestures made by the instructor in the video-based modeling examples, would help learners to focus their attention timely on the task aspects the model referred to. This study used the same water jug modeling examples as in Chapter 2, however, the conditions were slightly different, with the model (i) looking only straight into the camera (no cue condition), (ii) the model occasionally turning her head to the task display when mentioning an area of the task (gaze cue condition), or (iii) the model turning her head and making pointing and tracing gestures to the area(s) she referred to on the screen (gaze + gesture cue condition). Students' visual attention while studying the examples was recorded using eye tracking. Because human faces automatically draw people's attention (Tzourio-Mazoyer et al., 2002), it was hypothesized that the gaze + gesture cue condition compared with the other two conditions would improve learners' attention distribution between model and task, that is to timely switch their attention from the model to the task areas the model was talking about.

Part 2

Chapter 4 presents two experiments that investigated whether or not pointing toward picture locations could enhance spatial source memory for these locations, in young and older adults. Source memory has been found to decline with aging (Old & Naveh-Benjamin, 2008) and therefore it is important to investigate possible ways to improve this type of memory, especially in older adults. In the first experiment, it was investigated whether pointing at compared with naming the locations of the pictures would lead to higher source memory performance. In the second experiment, it was investigated whether pointing at compared with visual observation only of the locations of the pictures would lead to higher source memory performance. Because pointing gestures are visuospatially oriented (indexing or referring to objects or locations) it was hypothesized that pointing would improve source memory performance in both experiments. Because source memory performance is found to decline with aging (Old & Naveh-Benjamin, 2008), older adults might benefit more from gesturing and therefore, it was hypothesized that positive effects of gestures would be larger in older than in young adults.

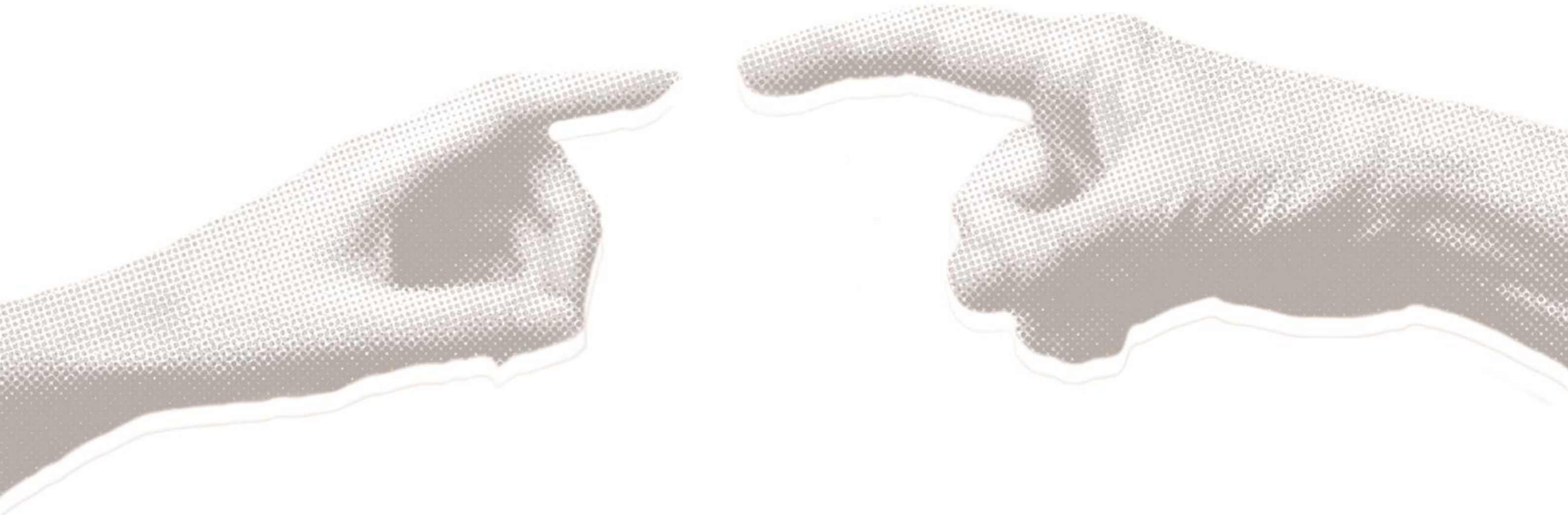
Chapter 5 presents two experiments that investigated whether or not pointing toward picture locations could enhance spatial source memory in children and young adults for these picture locations. In this study another factor was also added: picture-location congruency. A congruent picture location means that the location is consistent with dominant past experiences with the object or scene in the picture, such as a picture of a cloud presented at the upper half of the screen. A cloud presented at the lower half of the screen, would be an example of an incongruent picture location. It was hypothesized that pointing during encoding in addition to visual observation could enhance spatial source memory for picture-location pairs in children (Experiment 1) and young adults (Experiment 2) and because source memory is still developing in children (Cycowicz et al., 2001; Ruffman et al., 2001) children might benefit more from gesturing and therefore, it was hypothesized that positive effects of gestures would be larger in children than in young adults.

Chapter 6 presents two experiments that investigated whether or not pointing would enhance visuospatial working memory in young and older adults. For this study the visuospatial working memory paradigm was adopted from Chum, Bekkering, Dodd, and Pratt (2007). They had participants point at and visually observe (multimodal encoding strategy) or only visually observe (unimodal encoding strategy) sequences of simple figures consisting of two arrays (i.e., an array of three circles and an array of three squares) rapidly presented one by one at different locations on screen (encoding phase). Participants were instructed to point at one array and only visually observe the other (e.g., point at the circles and only observe the squares). Each trial consisted of an encoding phase (as just described) and a test phase. In the test phase one of the two arrays presented in the encoding phase was tested and participants were presented with a configuration of either the squares or the circles. They had to judge whether the locations of the figures were consistent or not with those in the encoding phase. Results showed that the multimodal encoding strategy led to improved spatial working memory performance compared with the unimodal encoding strategy. In addition, a recency effect was found in that performance on the stimuli presented more closely to the test phase was better than for those presented at a larger temporal distance. Experiment 1 compared young and older adults' performance on the paradigm from Chum et al. (2007). It was hypothesized that the beneficial effect of pointing and the recency effect found by Chum et al. would be replicated in young adults and would extend to older adults. Experiment 2 investigated whether or not the recency effect found by Chum et al., would purely stem from a difference in temporal proximity or also from interference from the irrelevant stimuli (i.e., the array that was not tested). It was hypothesized that predictive cues (cueing before the encoding phase whether the circles or the squares were to be tested) would ameliorate the temporal proximity effect.

Finally, in **Chapter 7**, the results from all studies in this dissertation are summarized and discussed in terms of theoretical and practical implications.

Chapter 2

Effects of gestures on older adults’ learning from video-based models



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Note that some minor changes have been made in this version compared to the published version, to align the layout and wording with the rest of the dissertation.

Abstract

This study investigated whether the positive effects of gestures on learning by decreasing working memory load, found in children and young adults, also apply to older adults, who might especially benefit from gestures given memory deficits associated with aging. Participants learned a problem-solving skill by observing a video-based modeling example, with the human model using gesture cues, with symbolic (arrow) cues, or without cues. It was expected that gesture compared with symbolic or no cues (i) improves learning and transfer performance, (ii) more in complex than simple problems, and (iii) especially in older adults. Although older adults' learning outcomes were lower overall than that of children and young adults, the results only revealed a time-on-task advantage of gesture over no cues in the learning phase for the older adults. In conclusion, the present study did not provide strong support for the effectiveness of gestures on learning from video-based modeling examples.

Introduction

In the past few decades, the Internet has become a popular source for learning from instructional videos. It is not only popular for young people, but older adults are also increasingly using the Internet (Chen & Persson, 2002). A case study among Canadian older adults suggests that although this group uses the Internet mainly for communication purposes, instructional videos on learning how to do something at home and videos made by peers and colleagues (video-modeling examples) are also regularly used (Milliken, O'Donnell, Gibson, & Daniels, 2012). However, not much is known about what determines the effectiveness of such videos in general and even less about how we can optimize such videos for older adults.

One major difference between young and older adults that might affect older adults' learning from video instructions involves age-related declines in working memory. Specifically, working memory (WM) functions that are prerequisites for learning, such as cognitive control, integrative processes, and speed of information processing, are suboptimal in older adults (Braver & Barch, 2002; Salthouse, 1996) and children (Friedman, Nessler, Cycowicz, & Horton, 2009; Kail, 2000). Fortunately, it seems possible to design instructions that may compensate for these negative age-related effects on learning. Research within the theoretical framework of cognitive load theory (Paas, Renkl, & Sweller, 2003; Sweller, Ayres, & Kalyuga, 2011; Sweller, Van Merriënboer, & Paas, 1998) has shown that instructional designs that take these age-related working memory declines into account may enhance learning performance overall, but especially when working memory functioning is challenged, as in older adults (e.g., Van Gerven, Paas, Van Merriënboer, & Schmidt, 2002), and when task complexity increases (Mayr & Kliegl, 1993; Oberauer & Kliegl, 2001; Paas & Van Merriënboer, 1994).

For example, in line with previous research with young adults on the goal-free effect (e.g., Sweller & Levine, 1982), Paas, Camp, and Rikers (2001) showed that maze learning from goal-free problems (location of goal exit was not visible) was more efficient than learning from goal-specific (location of goal exit was visible) problems, especially for older adults. The goal-free effect shows that for novices who have not yet acquired knowledge of effective problem-solving strategies, a goal-specific problem results in attempts to work backwards from the goal, which is a strategy that imposes high load on working memory but leads to learning only slowly. In the absence of a specific goal, learners explore the entire problem space and, in that process, acquire a schema of the operators involved in the solution procedure (Sweller et al., 2011). Compared with young adults, older adults have even more trouble with goal-specific problems because of age-related declines in attentional processes that are needed to plan subgoals and inhibitory processes to suppress the tendency to only make moves in the direction of the goal location (which was not the solution pathway; Paas et al., 2001).

Similarly, Van Gerven, Paas, Van Merriënboer, Hendriks, and Schmidt (2003) found that both young and older adults' learning from multimodal worked-out examples was more efficient than their learning from unimodal worked-out examples and goal-specific problems. Interestingly, these studies showed that the instructional methods that are inspired by cognitive load theory worked even better (Paas et al., 2001) or just as good (Van Gerven et al., 2003) for older adults than for young adults.

The main focus of the present study was on gesturing as an instructional method to foster older adults' learning of a novel problem-solving task when they observe video-based modeling examples. Learning by observing examples is very effective for acquiring new problem-solving skills (for reviews, see Atkinson, Derry, Renkl, & Wortham, 2000; Sweller et al., 1998; Van Gog & Rummel, 2010). Because of technological advancements, online video-based examples, in which a human model demonstrates and explains how to solve a certain problem, are increasingly being used. However, not much is known about what determines the quality of such examples. Moreover, because the Internet use by older adults is rapidly increasing (Chen & Persson, 2002) and age-related declines in working memory can hamper older adults' learning, it is especially important to investigate how to optimize video-based modeling examples for older adults.

The effectiveness of video-based modeling for older adults has been demonstrated with training and prevention purposes in health care, in which the learning goal was to imitate the motoric activities of the video model. For example, video-modeling examples on simple activities, such as how to manage activities of daily living (ADL; e.g., hand washing; Mihailidis, Boger, Craig, & Hoey, 2008), in patients with dementia, or how to do exercises that help to decrease fall risk (Clark & Kraemer, 2009; Haines et al., 2009), have been shown successful.

However, not much is known about video-based modeling examples teaching cognitively challenging tasks to older adults. Because life expectancy has increased massively (Oeppen & Vaupel, 2002) and the ongoing rapid changes in technological developments force people to continue learning at any age, we consider it important to investigate ways to facilitate learning, taking into account the age-related declines in cognitive control and processing speed.

The attentional cueing property of gestures

A significant amount of empirical evidence (e.g., Goldin-Meadow, Nusbaum, Kelly, & Wagner, 2001; Mayer & DaPra, 2012; Ping & Goldin-Meadow, 2008; Valenzeno, Alibali, & Klatzky, 2003) and theoretical evidence (e.g., Goldin-Meadow & Wagner, 2005; Paas & Sweller, 2012) suggests that adding a motoric component, in the form of gestures, to video-based modeling examples can improve learning and memory.

The present study takes a cognitive load theory perspective and proposes two main mechanisms that might underlie the positive effect of gestures on learning. First, gestures, and especially pointing gestures, might reduce cognitive load and foster integration, because a function of pointing gestures is attentional cueing. Second, because gestures provide motoric information, they also add another modality, which might have positive effects on learning (i.e., a modality effect).

With regard to the first mechanism, attentional cueing might be especially important for older adults, who have been found to have trouble integrating several features of an event into one memory (for a review, see Old & Naveh- Benjamin, 2008) and have difficulties with suppressing (responses to) irrelevant information, as evidenced by aging studies on the Stroop interference effect (Mathis, Schunk, Erb, Namer, & Luthringer, 2009; West & Alain, 2000). This competition for resources between relevant and irrelevant information can cause an increase in unnecessary cognitive load during learning, and we suggest that gestures can ameliorate this. For instance, in a video-based modeling example resembling a lecture situation (i.e., model standing next to a screen or blackboard displaying the task), pointing gestures made by the model can improve learning, by timely guiding participants' attention toward relevant aspects of the task. As a result, construction of a higher quality cognitive schema might be enhanced, and this cueing property of pointing gestures might be especially beneficial in populations with suboptimal cognitive control processes such as children (e.g., Friedman et al., 2009) and older adults (e.g., Braver & Barch, 2002; West & Alain, 2000).

Cognitive load theory research on learning from multimedia materials has provided evidence that cueing can have beneficial effects on learning (for reviews, see De Koning, Tabbers, Rikers, & Paas, 2009; Van Gog, 2014). However, cueing is not unique to gesturing, and indeed, most studies inspired by cognitive load theory have used symbolic cues or color cues (De Koning et al., 2009; Van Gog, 2014). Interestingly, literature on social cognition proposed that pointing is a primary (infants communicate by pointing even before they can speak) typical and uniquely human manner to elicit joint attention, cooperation, and shared intentions (Tomasello, Carpenter, & Liszkowski, 2007). In this respect, besides providing visual cues (as symbolic cues also do), gestures might also socially motivate learners to direct their attention to where or what the video model is referring to. For instance, Mayer and DaPra (2012) found an embodiment effect, that is, a positive effect on learning if the video-instructor (an animated agent) showed more human-like behavior (e.g., using a human, voice, gestures, and eye gaze). This study suggests that pointing gestures might improve learning because of an animacy effect, which might socially motivate the learner to attend to the information being pointed out, which in turn leads to deeper processing of the learning material. In the search for an answer to the question of whether pointing gestures have an additional effect above and beyond cueing, we consider it necessary to use symbolic cueing as a control condition.

Gestures and the modality effect

According to the second main mechanism by which gestures can positively affect learning, gestures might have an additional effect over symbolic cues, because of a modality effect. Prior cognitive load theory research has revealed a modality effect in the sense that presenting instruction to both the auditory and visual modality leads to superior learning compared with presenting instruction to only one modality (e.g., only visual; for a review, see Ginns, 2005). Cognitive load theory explains this modality effect in terms of a reduction of visual search and information integration processes, and better distribution of cognitive load over different working memory stores (i.e., visual and auditory) in multimodal instruction than in unimodal instruction (Van Gerven et al., 2003). According to this explanation, one might predict that presenting information in multiple modalities can enhance information processing especially when working memory is challenged, for example, in populations with suboptimal working memory functioning, such as children and older adults, or when task complexity is high.

Indeed, in older adults, learning from multimodal (visual and auditory) compared with unimodal worked examples has been found to increase learning efficiency (e.g., Van Gerven et al., 2003). In addition, other research has shown that presenting information in multiple modalities speeds up response times in a simple target detection task in young adults but significantly more in older adults (Laurienti, Burdette, Maldjian, & Wallace, 2006). This shows that multimodal information presentation can speed up information processing in older adults, a population that generally suffers from decreased cognitive speed (Salthouse, 1996). On the neural level, the modality effect can be explained by the finding that there are specific neurons in the superior temporal sulcus and inferior frontal gyrus that process multisensory information (i.e., visual and auditory). Importantly, these neurons produce more activation in reaction to bimodal information than the sum of activation of neurons responding to visual and auditory information in isolation. This effect is called multisensory enhancement, and shows that the human brain efficiently deals with multisensory information and integrates this at the early stage of encoding (Beauchamp, Lee, Argall, & Martin, 2004).

Interestingly, Holle, Obleser, Rueschemeyer, and Gunter (2010) recently showed that multisensory enhancement also occurs for multisensory information in the form of speech and gestures. Based on these findings regarding the modality effect on learning in general, the effect of multisensory information presentation on performance and response times in older adults, and multisensory enhancement in the brain for gesture–speech information, we propose that gestures used by a video-based model can reduce working memory load during learning and therefore is an effective instructional tool for older adults. By adding motoric information, gestures add another modality to an already multimodal video model. A recent study provided some evidence that this might foster learning. De Koning and Tabbers (2013) investigated the effect of gesture cues versus symbolic cues on learning about the formation of lightning from an instructional animation. In this animation, relevant areas were cued by a moving arrow, which participants had to observe or follow with their index finger (self-gesturing), or a picture of a hand moving in the same manner as the arrow in the other condition. Results showed superior learning from the animation in which participants observed the gesture cue, compared with observing the arrow cue or self-gesturing.

This finding can be explained from an embodied cognition perspective that states that our cognition is rooted in bodily interactions with the physical environment (Wilson, 2002) or in respect to the present study that learning is rooted in bodily experiences. According to this perspective, gestures are more than just visual cues, because gestures are also processed by the motor system. Thus, gesturing might improve learning by providing a richer cognitive schema, because gestures add an extra (motoric) modality to the learner's representation of the task. Moreover, evidence showed that this extra motor information is processed rather efficiently. For example, EEG research in young adults has shown that speech and its accompanying gestures are perceived and processed as an integrated whole (e.g., Kelly, Creigh, & Bartolotti, 2010). These findings suggest that observing an instructor presenting information in speech and gesture leads to the construction of higher quality cognitive schemas than observing an instructor who expresses the same information in speech only.

However, the positive effects of gestures on learning are largely based on studies with children and young adults. The present study proposes that gestures might not only be a useful instructional tool for tasks that impose a high demand on working memory but also for older adults who have a decrease in working memory functioning, because gestures are processed automatically (Kelly et al., 2010) and very efficiently (Holle et al., 2010). Moreover, most prior studies on effects of gesturing did not control for the cueing effect of gestures and therefore do not allow for conclusions on whether beneficial effects of gestures arise merely from cueing or from broader representational effects. The study by De Koning and Tabbers (2013) did compare a gesture to a symbolic cue. However, their gesture cue was a picture of a hand moving on the screen, which is very different from gestures made by an instructor.

The present study

Therefore, in the present study, the gesture condition showed a video of a human model explaining the problem-solving task while making gestures, whereas the cueing condition sees an arrow (i.e., symbolic cue) pointing toward the same locations, and the no cue control condition does not receive any cues. We hypothesize that cueing is better than no cueing for learning and that gestures (being bodily actions) made by a human agent can promote learning more than symbolic cues for two reasons. First, gestures would result in the construction of a richer problem schema by the learner, because gesture cues add a visual code as well as a motoric code to the learners' representation of the task. Because the motoric information is automatically processed (Rizzolatti & Craighero, 2004; Rizzolatti, Fogassi, & Gallese, 2006), that is, outside of the limited capacity working memory, this richer learning outcome (i.e. schema) is achieved without additional working memory load. Second, in the gesturing condition, the auditory (verbal) and visual/motoric (gesture cues) information is produced by the same source (the human model). Because we tend to look at other people's faces when they speak to us, even on video (e.g., Gullberg & Holmqvist, 2006), a gesture made by the model will be easy to follow (i.e., requiring less integrative processing and therefore less working memory resources from the learner), whereas in a symbolic cue condition, the auditory (verbal) information comes from the model and the visual information (arrow cues) comes from another source. So even though arrows have potential to attract and guide attention, they might not be attended to as fast as the gestures. In short, gestures are expected to enhance learning more than symbolic cues because they reduce cognitive load otherwise spent on reducing split attention between the model and the task.

In sum, the present study will compare the effect of deictic gestures (pointing and tracing) to symbolic (arrow) cues and no pointing cues in instruction on learning a novel problem-solving task. In this way, it was possible to investigate whether a potential positive effect of gestures on learning could be explained by the cueing effect or by the modality effect. Based on the modality explanation, it was hypothesized that an instruction using gesture cues compared with no cues or symbolic cues would impose a lower cognitive load and lead to better and faster performance on isomorphic (similar structure as the problem presented during the learning phase but different values) and transfer problems (different structure as the problem presented during the learning phase) within each age group. Because complex problems require more working memory resources than simple problems, it was expected that the positive effect of gestures would be more pronounced for complex than simple problem solving. Furthermore, between age groups, it was expected that young adults would outperform children and older adults.

Method

The effect of gesture versus symbolic cues or no cues on learning a novel problem-solving task from a video-based model was investigated.

Participants and design

Participants were 92 children, 59 young adults, and 88 older adults. The children (41 girls and 51 boys, M_{age} = 11.3 years, *SD* = 0.7 years, age range: 9–12 years) were from the seventh and eighth grade of Dutch elementary school (which is comparable to the fifth and sixth grade in the USA) and were recruited via invitation letters to the schools. For their participation, the children received a small present. The young adults (48 women and 11 men, M_{age} = 20.7 years, *SD* = 2.2 years, age range: 18–31 years) were recruited from the

Erasmus University student pool and received course credits. The older adults were recruited via advertisements in local newspapers that called for healthy older adults from age 50 years. Five participants mentioned only after the experiment that they suffered a minor head trauma in the past. These participants were excluded from the analyses. This left a sample of 83 older adults (55 women, 28 men, M_{age} = 67.4 years, *SD* = 7.7 years, age range 50–86 years). Participants were randomly assigned to one of three instruction conditions (Figure 1).

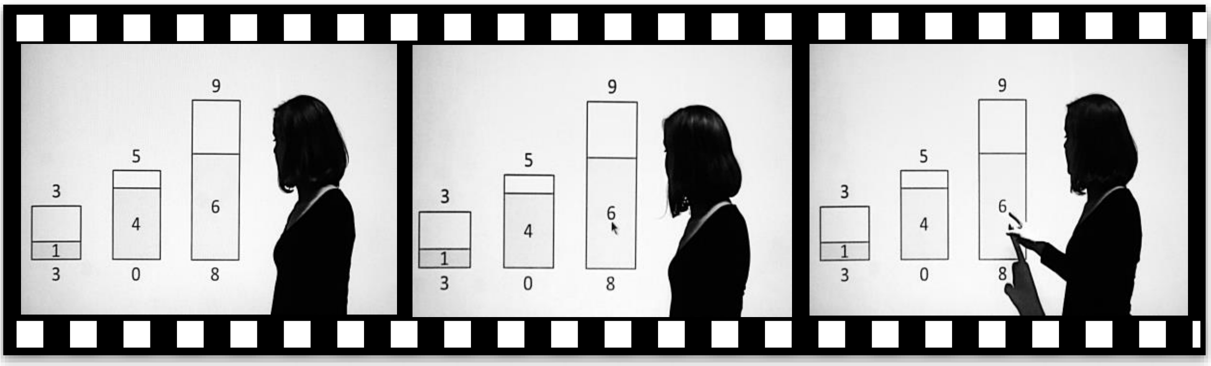


Figure 1. Snapshot of each of the three video-instruction conditions, from left to right; no cue, symbolic cue and gesture cue condition.

In all conditions a videotaped instructor explained how to solve the problems verbally, and depending on the assigned condition, the instructor (i) made no gestures (i.e., no-cue instruction), (ii) made no gestures, but an arrow on the screen pointed at the relevant locations when these were being mentioned (i.e., symbolic-cue instruction), or (iii) made pointing and tracing gestures toward the relevant locations on the screen displaying the task (i.e., gesture-cue instruction).

Materials

All materials were programmed in E-prime 2.0.

Raven Standard Progressive Matrices. As a check on random assignment, the Raven standard progressive matrices test (Raven SPM; Raven, Court, & Raven, 1985) was used to assess whether participants' baseline level of fluid intelligence (which is related to novel problem-solving ability; Raven et al., 1985) did not differ across conditions within each age group.

Learning phase. The learning task that was created for this experiment was an adapted version from Luchins' (1942) water jug task, based on the water redistribution paradigm used by Schmid, Wirth, and Polkehn (2003). In this task, participants needed to proceed from an initial state to a goal state by pouring water from one jug into another one. This redistribution of water was constrained by a task rule: the donating jug always tried to empty its entire content into the receiving jug. However, when the receiving jug did not have enough capacity for the content of a donating jug, the receiving jug was filled to the brim, leaving the donating jug with the residual. For the present study, a computerized version of the water redistribution task was created in E-prime 2.0. In this task, participants could redistribute water through mouse clicks on the jugs. See Figure 2 for an example.

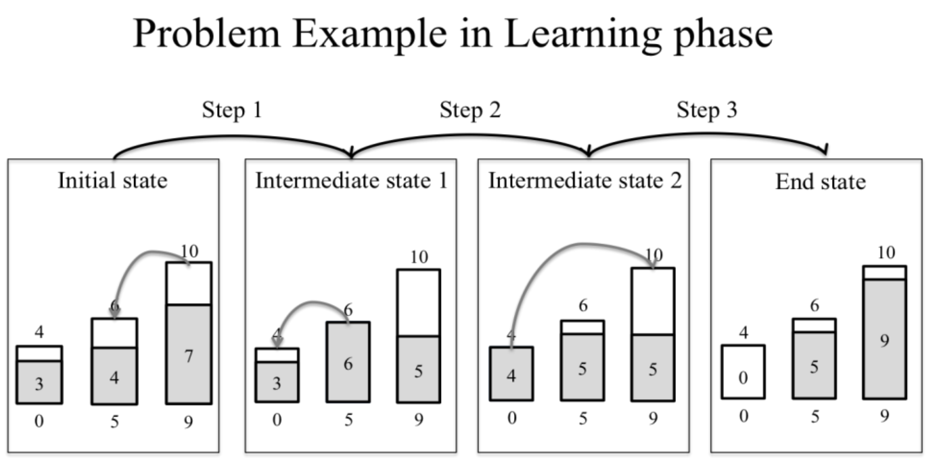


Figure 2. Example of a three-step water redistribution problem in the learning phase. The goal amount is represented in the numbers under the jugs, the maximal amount by the numbers above the jugs, and the current amounts by the numbers in the jugs.

For example, to pour water from jug A into jug B, participants first had to click on the jug they wanted to pour water from (the donating jug, in the example jug A; water in this jug changed color as a visual confirmation that it was selected) and, second, on the jug they wanted to pour water into (the receiving jug, in this example jug B). With the second click, the water levels of the jugs changed according to the task rule.

Two problem categories were created: simple and complex problems. Complexity was defined by whether the first step in the shortest solution strategy reduced the evaluation factor (EVF; Carder, Handley, & Perfect, 2008), that is, the sum of differences between the goal content and current content for each jug. Simple problems had a perceptually consistent solution strategy, because each step perceptually decreased the EVF. The solution strategy for complex tasks was either perceptually neutral (EVF remains the same) or counterintuitive (EVF increases) after the first step in the shortest solution pathway. Because in the perceptually consistent strategy, problem solvers had to look at only one move ahead, it was less demanding for working memory than a perceptually neutral or counterintuitive strategy (Carder et al., 2008), which required problem solvers to look at more than one move ahead (Bull, Espy, & Senn, 2004). Each problem category consisted of two problems with a two-step solution and two problems with a three-step solution. In total, the learning phase consisted of four video examples, which were each followed by two corresponding isomorphic problem-solving tasks (i.e., example–problem–problem and example–problem–problem) in the following order: (i) two-step simple problems (EVF decreases after first correct step); (ii) two-step complex problems (EVF does not decrease after first correct step); (iii) three-step simple problems (EVF decreases after first correct step); and (iv) three-step complex problems (EVF increases after first correct step). While working on the problems, perceived mental effort was measured with a mental effort rating scale, which is considered an indicator of experienced cognitive load (Paas, Tuovinen, Tabbers, & Van Gerven, 2003; Paas, Van Merriënboer, & Adam, 1994). The mental effort scale was adapted from Paas (1992) and consisted of labeled values from 0 = no mental effort to 9 = extremely high mental effort. Participants had to press the number on the keyboard that corresponded to the value they chose for their experienced mental effort.

For each type of instruction, five videos were recorded showing a general explanation of the tasks and four modeling examples in which it was demonstrated how to solve each of the problem types. In all types of video instruction, the instructor gave the same verbal explanation and made head movements toward the screen displaying the task and the camera (i.e., facing the observing participant). Additionally, in the gesture and symbolic cue instruction conditions, the cues pointed to locations (e.g., jugs and numbers) the instructor verbally referred to and traced the pathway of one jug to another when verbally explaining a pouring step. The videos for the learning task were recorded with a digital video camera and edited in Final Cut Pro 7.0.3. All videos showed the same female instructor explaining the task.

Transfer task. A transfer task was created, based on a verification paradigm designed by Carder et al. (2008). Participants were presented with three-step problems in which the first step was given by a picture of the initial state and the state after one step. The participants had to judge whether this step was correct or incorrect. Figure 3 provides an example of an item. The transfer task consisted of 16 simple and 16 complex three-step problems that needed to be judged as correct or incorrect. Whereas simple trials had to be answered following the perceptual strategy, complex trials had to be answered following the counterintuitive strategy.

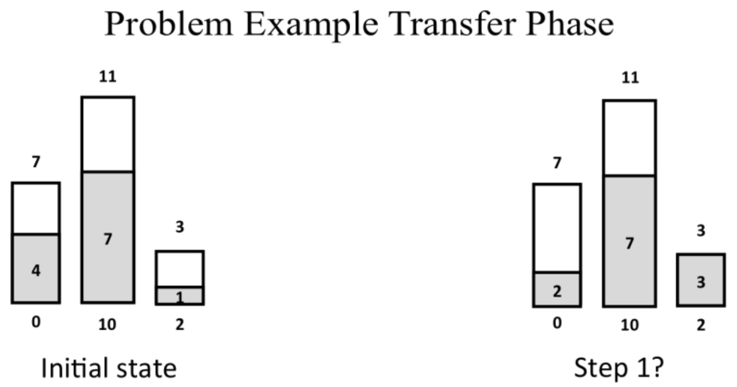


Figure 3**.** Example of a problem in the transfer task. Participants had to judge whether step 1 presented on the right, was a correct or incorrect first step in a three-step solution.

Procedure

The children were individually tested in a separate room in their schools, the young adults in a quiet room at the University, and the older adults in a quiet room in a community center in their neighborhood. First, demographic data were collected (gender and age). Then, the learning task started, with a video showing the instructor giving a general explanation of the task rules. After this, participants received a training in which they practiced how to redistribute the water between jugs in the computer-based task. When they were familiarized with this procedure, participants received an experimental learning trial for each problem category. Each trial began with a video-modeling example in which an instructor demonstrated and explained how to solve this type of problem. Each modeling example was immediately followed by the two practice problems of the same problem type. Participants got a maximum of 60 s for each problem, after which the test automatically progressed to the mental effort rating scale. After participants had rated their mental effort, the experiment proceeded automatically. All learning tasks (example–problem–problem; example–problem–problem; etc.) were presented in a fixed order progressing from the most simple to the most complex problem category.

Next, in the transfer task, participants had a maximum of 30 s per trial to make their judgments by pressing ‘1’ for correct and ‘0’ for incorrect. After the participants responded or when the time limit was reached, the experiment automatically proceeded to the mental effort scale. After participants rated their mental effort, the experiment automatically proceeded. For all participants, the trials were presented in the same randomized order. Finally, participants had 20 min to complete the Raven SPM.

Data analysis

For performance on the Raven SPM, one point was assigned to each correct answer. The sum of correct answers per individual was corrected for age and gender and converted into percentile scores.

In the learning task, for each problem solved, performance scores were obtained by dividing the number of steps in the shortest possible solution, by the actual number of steps a participant needed to solve the problem. For example, if participant A solved a two-step problem in two steps and participant B solved the same problem in 10 steps, this would result in a score of 1 for A and 0.2 for B. In the transfer test, one point was given for each correct answer. Performance was defined by the total amount of correct answers. Time on task was determined by the mean time (s) participants worked on a problem. Mental effort was defined by the responses on the subjective rating scale that participants gave after each problem.

Results and discussion

First, analyses testing the effect of instruction on learning efficiency were conducted for each age group separately; performance, time on task, and mental effort were analyzed with 3 × 2 ANOVAs with type of instruction (no cue, symbolic cue, or gesture cue) as a between-subjects factor and task complexity (simple vs. complex) as a within-subjects factor. Second, a between age groups analysis was carried out with 3 × 3 ANOVAs with age group and instruction condition as between-subjects variables. For all analyses, a significance level of .05 was used. The mean squared error was used as an index of the predictive value of the independent variables (Allen, 1971). Partial eta-squared (η_p^2) was calculated as a measure of effect size, with values of .01, .06, and .14 characterizing small, medium, and large effect sizes, respectively (Cohen, 1988).

Children

Raven Progressive Matrices. A one way ANOVA revealed no differences on the Raven scores between the no cue group (*M* = 59.45, *SD* = 45.78), symbolic cue group (*M* = 75.90, *SD* = 40.42), and the gesture cue group (*M* = 67.77, *SD* = 43.96), $F(2, 89) = 1.11$, *MSE* = 1886.81, $p = .334$, $\eta_p^2 = .02$.

Learning phase. Means and standard deviations of the children's performance, time on task and mental effort in the learning phase can be found in Table 1.

Table 1.
Means (and SD) of the Children's Learning Phase Performance, Time on Task and Mental Effort

	Type of instruction	No cue (n = 31)		Symbolic cue (n = 31)		Gesture cue (n = 30)	
		M	*SD*	*M*	*SD*	*M*	*SD*
Total solved in %		58.87	19.15	58.06	15.99	64.17	18.78
Performance score	Simple	0.88	0.48	0.93	0.53	1.02	0.56
	Complex	0.77	0.49	0.62	0.44	0.66	0.50
	Mean	0.83	0.40	0.78	0.41	0.84	0.42
Time on task (s)	Simple	32.76	11.44	31.11	12.07	28.27	11.78
	Complex	48.75	13.60	49.97	12.22	43.54	13.72
	Mean	34.41	9.91	34.28	9.05	31.68	9.30
Mental effort	Simple	2.86	1.67	2.77	1.68	2.59	2.01
	Complex	3.75	2.10	3.81	1.88	3.49	2.10
	Mean	3.31	1.74	3.29	1.66	3.04	1.90

Note. N = 92. Total solved in % = the percentage of problems solved (8 = 100%). Mean = average over all problems. Simple = average for problems with a perceptually consistent strategy. Complex = average for problems with a perceptually neutral or a counterintuitive strategy.

On performance, results showed no effect of type of instruction, $F(2, 89) = 0.20$, $MSE = 0.34$, $p = .822$, $\eta_p^2 < .01$. There was a main effect of task complexity, $F(1, 89) = 18.46$, $MSE = 0.17$, $p < .001$, $\eta_p^2 = .17$, reflecting better performance on the simple than the complex problems. There was no interaction effect, $F(2, 89) = 1.54$, $MSE = 0.17$, $p = .221$, $\eta_p^2 = .03$.

On time on task, there was no effect of type of instruction, $F(2, 89) = 1.65$, $MSE = 275.23$, $p = .197$, $\eta_p^2 = .04$, an effect of task complexity, $F(1, 89) = 344.31$, $MSE = 37.28$, $p < .001$, $\eta_p^2 = .80$, but no interaction effect, $F(2, 89) = 1.48$, $MSE = 37.28$, $p = .233$, $\eta_p^2 = .03$.

On mental effort, there was no effect of type of instruction, $F(2, 89) = 0.21$, $MSE = 6.25$, $p = .808$, $\eta_p^2 = .01$. There was a main effect of task complexity, $F(1, 89) = 37.99$, $MSE = 1.08$, $p < .001$, $\eta_p^2 = .30$, reflecting less mental effort being invested in the simple than in the complex problems. There was no interaction effect of task complexity and type of instruction, $F(2, 89) = 0.12$, $MSE = 1.08$, $p = .892$, $\eta_p^2 < .01$.

In sum the children had more trouble solving the complex than the simple problems, reflected by lower accuracy, higher time on task, and higher perceived mental effort. However, type of instruction (no cue, arrow cue or gesture cue) did not influence learning performance, time on task, or mental effort.

Transfer test. Means and standard deviations of the children's performance, time on task and mental effort in the transfer test can be found in Table 2.

Table 2.
Means (and SD) of the Children's Transfer Performance, Time on Task and Mental Effort

	Type of instruction	No cue (n = 31)		Symbolic cue (n = 31)		Gesture cue (n = 30)	
		M	*SD*	*M*	*SD*	*M*	*SD*
Performance	Simple	11.64	2.96	11.32	3.80	11.00	2.75
	Complex	7.32	1.94	7.84	2.24	7.30	2.28
	Mean	18.97	3.83	19.16	5.28	18.30	4.05
Time on task (s)	Simple	14.62	3.76	14.05	4.87	14.05	4.64
	Complex	16.13	4.39	14.73	5.15	15.43	5.56
	Mean	15.38	3.80	14.39	4.87	14.74	4.96
Mental effort	Simple	2.18	1.68	2.50	1.79	2.46	2.17
	Complex	2.84	1.95	2.81	2.07	2.68	2.26
	Mean	2.51	1.78	2.65	1.90	2.57	2.20

Note. N = 92. Mean = average over all problems. Simple = average for problems with a perceptually consistent strategy. Complex = average for problems with a counterintuitive strategy.

On performance, results showed no effect of type of instruction, $F(2, 89) = 0.32$, MSE = 9.85, $p = .731$, $\eta_p^2 = .01$.There was a main effect for task complexity, $F(1, 89) = 133.09$, MSE = 5.08, $p < .001$, $\eta_p^2 = .60$, reflecting better performance on the simple than the complex problems, but there was no interaction effect, $F(2, 89) = 0.58$, MSE = 5.08, $p = .564$, $\eta_p^2 = .01$.

On time on task, results showed no effect of type of instruction, $F(2, 89) = 0.38$, MSE = 41.76, $p = .688$, $\eta_p^2 = .01$, a main effect of task complexity, $F(1, 89) = 18.28$, MSE = 3.54, $p < .001$, $\eta_p^2 = .17$, reflecting smaller time on task on the simple than the complex problems, but no interaction effect of task complexity and type of instruction, $F(2, 89) = 0.87$, MSE = 3.54, $p = .423$, $\eta_p^2 = .02$.

On mental effort, results showed no effect of type of instruction, $F(2, 89) = 0.04$, MSE = 7.74, $p = .958$, $\eta_p^2 < .01$, a main effect of task complexity, $F(1, 89) = 35.24$, MSE = 0.21, $p < .001$, $\eta_p^2 = .28$, reflecting lower mental effort on the simple than the complex problems and an interaction effect between task complexity and type of instruction, $F(2, 89) = 4.12$, MSE = 0.21, $p = .020$, $\eta_p^2 = .09$. To determine the locus of the interaction effect of type of instruction and complexity, separate ANOVAs, with an adjusted alpha level of .05/2 = .025, were conducted on mental effort for the simple and complex problems. No effect of instruction was found on the simple problems, $F(2, 89) = 0.26$, MSE = 3.57, $p = .767$, $\eta_p^2 < .01$, or the complex problems, $F(2, 89) = 0.05$, MSE = 4.38, $p = .949$, $\eta_p^2 < .01$.

In sum, also on the transfer test did the children have more trouble solving the complex than the simple problems, which was reflected by lower accuracy, higher time on task, and higher perceived mental effort. However, type of instruction (no cue, arrow cue or gesture cue) did not influence transfer performance, time on task, or mental effort on the transfer test.

Young adults

Raven Progressive Matrices. Results revealed no differences on the Raven scores between the no cue group (*M* = 67.09, *SD* = 30.38), symbolic cue group (*M* = 69.00, *SD* = 33.02), and the gesture cue group (*M* = 75.74, *SD* = 27.30), $F(2, 56) = 0.45$, $MSE = 916.49$, $p = .643$, $\eta_p^2 = 02$.

Learning phase. Means and standard deviations of the young adults' performance, time on task and mental effort in the learning phase can be found in Table 3.

Table 3.
Means (and SD) of the Young Adults' Learning Phase Performance, Time on Task and Mental Effort

	Type of instruction	No cue (*n* = 22)		Symbolic cue (*n* = 18)		Gesture cue (*n* = 19)	
		M	*SD*	*M*	*SD*	*M*	*SD*
Total solved in %		88.07	12.49	89.58	16.18	90.79	16.05
Performance score	Simple	1.59	0.47	1.73	0.47	1.63	0.46
	Complex	1.30	0.65	1.59	0.60	1.58	0.36
	Mean	1.45	0.50	1.66	0.45	1.61	0.35
Time on task (s)	Simple	19.88	11.79	17.22	10.51	16.37	8.40
	Complex	19.66	15.45	18.47	13.05	20.86	14.00
	Mean	17.99	10.95	16.82	9.91	17.60	8.79
Mental effort	Simple	1.64	1.31	2.32	1.68	1.89	1.38
	Complex	2.69	1.98	2.97	2.05	2.17	1.57
	Mean	2.24	1.42	2.65	1.58	1.85	1.11

Note. N = 59. Total solved in % = the percentage of problems solved (8 = 100%). Mean = average over all problems. Simple = average for problems with a perceptually consistent strategy. Complex = average for problems with a perceptually neutral or a counterintuitive strategy.

On performance, results showed no effect of type of instruction, $F(2, 56) = 1.32$, $MSE = 0.39$, $p = .274$, $\eta_p^2 = .05$, a main effect of task complexity, $F(1, 56) = 5.43$, $MSE = 0.14$, $p = .023$, $\eta_p^2 = .09$, reflecting better performance on the simple than the complex problems, but no interaction effect, $F(2, 56) = 1.09$, $MSE = 0.14$, $p = .342$, $\eta_p^2 = .04$.

On time on task, there was no effect of type of instruction, $F(2, 56) = 0.13$, $MSE = 258.47$, $p = .876$, $\eta_p^2 = .01$, or task complexity, $F(1, 56) = 3.68$, $MSE = 26.95$, $p = .060$, $\eta_p^2 = .06$, nor an interaction effect, $F(2, 56) = 2.16$, $MSE = 26.95$, $p = .124$, $\eta_p^2 = .07$.

On mental effort, there was no effect of type of instruction, $F(2, 56) = 0.93$, $MSE = 4.14$, $p = .400$, $\eta_p^2 = .03$, a main effect of task complexity, $F(1, 56) = 8.52$, $MSE = 1.51$, $p = .005$, $\eta_p^2 = .31$, reflecting lower mental effort on the simple than the complex problems but no interaction effect of task complexity and type of instruction, $F(2, 56) = 1.03$, $MSE = 1.51$, $p = .362$, $\eta_p^2 = .04$.

In sum, the young adults had more trouble solving the complex than the simple problems, reflected by lower accuracy, and higher perceived mental effort. However, there was no effect of complexity on time on task. Type of instruction (no cue, arrow cue or gesture cue) did not influence learning performance, time on task, or mental effort.

Transfer test. Means and standard deviations of the young adults' performance, time on task and mental effort in the transfer test can be found in Table 4.

Table 4.
Means (and SD) of the Young Adults' Transfer Performance, Time on Task and Mental Effort

	Type of instruction	No cue (*n* = 21)		Symbolic cue (*n* = 17)		Gesture (*n* = 18)	
		M	*SD*	*M*	*SD*	*M*	*SD*
Performance	Simple	13.57	1.91	11.65	2.26	12.67	2.20
	Complex	8.24	2.07	8.53	1.37	9.44	2.06
	Mean	21.81	3.31	20.18	3.05	22.11	3.20
Time on task (s)	Simple	14.82	3.94	15.23	4.67	12.97	5.36
	Complex	16.69	3.97	15.78	4.17	14.70	5.50
	Mean	15.75	3.87	15.50	4.32	13.84	5.35
Mental effort	Simple	4.24	1.67	4.61	1.68	4.15	2.00
	Complex	4.41	1.64	4.77	1.81	4.43	1.84
	Mean	4.36	1.70	4.72	1.87	4.39	1.86

Note. $N = 56$. Mean = average over all problems. Simple = average for problems with a perceptually consistent strategy. Complex = average for problems with a counterintuitive strategy.

On performance, results showed no effect of type of instruction, $F(2, 53) = 1.86$, $MSE = 5.11$, $p = .165$, $\eta_p^2 = .07$, a main effect of task complexity, $F(2, 53) = 144.02$, $MSE = 2.92$, $p < .001$, $\eta_p^2 = .73$, reflecting better performance on the simple than the complex problems, and an interaction effect, $F(2, 53) = 5.26$, $MSE = 2.92$, $p = .008$, $\eta_p^2 = .17$. To determine the locus of the interaction effect of type of instruction and complexity, separate ANOVAs were conducted on the simple and complex problems. On performance an effect of instruction was present on the simple problems, $F(2, 53) = 3.89$, $MSE = 4.47$, $p = .026$, $\eta_p^2 = .13$, but not on the complex problems, $F(2, 53) = 2.10$, $MSE = 3.56$, $p = .132$, $\eta_p^2 = .07$. Multiple comparisons with an adjusted alpha level of .05/3 = .017, showed that participants in the no cue condition outperformed the participants in the symbolic cue condition, $F(1, 36) = 8.08$, $MSE = 4.31$, $p = .007$, $\eta_p^2 = .18$. No such difference was found between the no cue and gesture cue condition, $F(1, 37) = 1.89$, $MSE = 4.19$, $p = .177$, $\eta_p^2 = .05$, and between the gesture cue condition and symbolic cue condition, $F(1, 33) = 1.83$, $MSE = 4.97$, $p = .185$, $\eta_p^2 = .05$.

On time on task, results showed no effect of type of instruction, $F(2, 53) = 0.99$, $MSE = 40.89$, $p = .379$, $\eta_p^2 = .04$, a main effect of task complexity, $F(1, 53) = 32.64$, $MSE = 1.63$, $p < .001$, $\eta_p^2 = .38$, reflecting less time on task on the simple than the complex problems, but no interaction effect of task complexity and type of instruction, $F(2, 53) = 2.90$, $MSE = 1.63$, $p = .064$, $\eta_p^2 = .10$.

On mental effort, results showed no effect of type of instruction, $F(2, 53) = 0.29$, $MSE = 6.03$, $p = .753$, $\eta_p^2 = .01$, a main effect of task complexity, $F(1, 53) = 4.44$, $MSE = 0.25$, $p = .040$, $\eta_p^2 = .08$, reflecting lower mental effort on the simple than the complex problems, but no interaction effect between task complexity and type of instruction, $F(2, 53) = 0.16$, $MSE = 0.25$, $p = .851$, $\eta_p^2 = .01$.

In sum, also on the transfer test did the young adults have more trouble solving the complex than the simple problems, reflected by lower accuracy, higher time on task, and higher perceived mental effort. Interestingly, participants in the no cue condition outperformed those in the arrow cue condition on transfer performance on the simple problems. We will return to that finding in the general discussion.

Older adults

Raven Progressive Matrices. Results revealed no differences on the Raven scores between the no cue group ($M = 81.89$, $SD = 29.50$), symbolic cue group ($M = 78.12$, $SD = 31.79$), and the gesture cue group ($M = 63.57$, $SD = 36.07$), $F(2, 80) = 2.54$, $p = .085$ $MSE = 1068.61$. $\eta_p^2 = .06$.

Learning phase. Means and standard deviations of the older adults' performance, time on task and mental effort in the learning phase can be found in Table 5.

On performance, results showed no effect of type of instruction, $F(2, 80) = 1.20$, $MSE = 0.45$, $p = .308$, $\eta_p^2 = .03$, a main effect of task complexity, $F(1, 80) = 24.97$, $MSE = 0.13$, $p < .001$, $\eta_p^2 = .24$, reflecting better performance on the simple than the complex problems, but no interaction effect, $F(2, 80) = 1.75$, $MSE = 0.13$, $p = .180$, $\eta_p^2 = .04$.

On time on task, however, there was a main effect of type of instruction, $F(2, 80) = 5.22$, $MSE = 248.87$, $p = .007$, $\eta_p^2 = .12$, and task complexity, $F(1, 80) = 90.32$, $MSE = 44.21$, $p < .001$, $\eta_p^2 = .05$, reflecting less time on task on the simple than the complex problems, but no interaction effect, $F(1, 80) = 0.65$, $MSE = 44.21$, $p = .523$, $\eta_p^2 = .02$. To determine the locus of the main effect for type of instruction, multiple comparisons with an adjusted alpha level of .05/3 = .017 were conducted to compare time on task between the different conditions. It was found that participants in the gesture cue condition spent significantly less time on problem solving than participants in the no cue condition, $F(1, 56) = 9.71$, $MSE = 96.44$, $p = .003$, $\eta_p^2 = .15$. No such difference was found between the no cue and symbolic cue condition, $F(1, 53) = 4.05$, $MSE = 91.69$, $p = .049$, $\eta_p^2 = .07$, or between the gesture cue condition and symbolic cue condition $F(1, 51) = 0.90$, $MSE = 117.26$, $p = .349$, $\eta_p^2 = .02$.

On mental effort, there was no effect of type of instruction, $F(2, 80) = 0.63$, $MSE = 7.08$, $p = .536$, $\eta_p^2 = .02$, a main effect of task complexity, $F(1, 80) = 36.35$, $MSE = 1.26$, $p < .001$, $\eta_p^2 = .31$, reflecting lower mental effort on the simple than the complex problems, but no interaction effect of task complexity and type of instruction, $F(2, 80) = 0.65$, $MSE = 1.26$, $p = .526$, $\eta_p^2 = .02$.

In sum, the older adults had more trouble solving the complex than the simple problems, reflected by lower accuracy, higher time on task, and higher perceived mental effort. Interestingly, participants in the gesture cue condition solved the problems faster than those in the no cue condition.

Table 5.
Means (and SD) of the Older Adults' Learning Phase Performance, Time on Task and Mental Effort

	Type of instruction	No cue (*n* = 30)		Symbolic cue (*n* = 25)		Gesture cue (*n* = 28)	
		M	*SD*	*M*	*SD*	*M*	*SD*
Total solved In %		40.42	19.61	51.50	25.08	50.89	22.29
Performance score	Simple	0.87	0.51	0.97	0.59	0.87	0.56
	Complex	0.45	0.45	0.72	0.59	0.70	0.54
	Mean	0.66	0.42	0.85	0.53	0.79	0.47
Time on task (s)	Simple	43.19	11.84	36.69	11.79	35.79	13.45
	Complex	54.67	8.32	45.65	14.44	44.87	12.40
	Mean	43.70	8.59	38.48	10.64	35.66	10.99
Mental effort	Simple	3.87	1.85	3.25	2.24	3.96	1.84
	Complex	4.98	2.23	4.52	2.25	4.74	1.84
	Mean	4.42	1.94	3.89	2.12	4.35	1.57

Note. *N* = 83. Total solved in % = the percentage of problems solved (8 = 100%). Mean = average over all problems. Simple = average for problems with a perceptually consistent strategy. Complex = average for problems with a perceptually neutral or a counterintuitive strategy.

Transfer test. Means and standard deviations of the older adults' performance, time on task and mental effort in the transfer test can be found in Table 6.

On performance, results showed no effect of type of instruction, $F(2, 80) = 1.09$, $MSE = 8.29$, $p = .343$, $\eta_p^2 = .03$, a main effect of task complexity, $F(1, 80) = 54.47$, $MSE = 4.87$, $p < .001$, $\eta_p^2 = .41$, reflecting better performance on the simple than the complex problems, but no interaction effect, $F(2, 80) = 1.09$, $MSE = 4.87$, $p = .341$, $\eta_p^2 = .03$.

On time on task, results showed no effect of type of instruction, $F(2, 80) = 1.11$, $MSE = 35.38$, $p = .333$, $\eta_p^2 = .03$, a main effect of task complexity, $F(1, 80) = 61.88$, $MSE = 2.78$, $p < .001$, $\eta_p^2 = .44$, reflecting less time on task on the simple than the complex problems, but no interaction effect of task complexity and type of instruction, $F(2, 80) = 0.18$, $MSE = 2.78$, $p = .837$, $\eta_p^2 < .01$.

On mental effort, results showed no effect of type of instruction, $F(2, 80) = 1.75$, $MSE = 24.52$, $p = .181$, $\eta_p^2 = .04$, no main effect of task complexity, $F(1, 80) = 1.25$, $MSE = 13.06$, $p = .267$, $\eta_p^2 = .02$, and no interaction effect between task complexity and type of instruction, $F(2, 80) = 1.49$, $MSE = 13.06$, $p = .231$, $\eta_p^2 = .04$.

In sum, also on the transfer items did the older adults have more trouble solving the complex than the simple problems, reflected by lower accuracy and higher time on task. However, type of instruction (no cue, arrow cue or gesture cue) did not influence learning performance, time on task, or mental effort.

Table 6.
Means (and SD) of the Older Adults' Transfer Performance, Time on Task and Mental Effort

	Type of instruction	No cue (n = 30)		Symbolic cue (n = 25)		Gesture cue (n = 28)	
		M	*SD*	*M*	*SD*	*M*	*SD*
Performance	Simple	9.10	3.01	9.08	2.97	10.29	2.69
	Complex	7.07	2.23	6.72	2.19	7.07	2.14
	Mean	16.17	4.15	15.80	4.15	17.36	3.91
Time on task (s)	Simple	15.80	4.54	17.34	3.63	16.87	4.28
	complex	17.69	4.75	19.32	3.91	19.12	4.80
	Mean	16.74	4.49	18.33	3.65	17.99	4.34
Mental effort	Simple	3.51	2.09	4.07	2.31	6.24	9.33
	Complex	3.59	2.13	4.11	2.63	4.24	1.96
	Mean	3.55	2.07	4.09	2.45	4.40	1.93

Note. N = 83. Mean = average over all problems. Simple = average for problems with a perceptually consistent strategy. Complex = average for problems with a counterintuitive strategy.

Age, instruction condition and learning and transfer performance

The analyses between age groups (see Table 7) showed a main effect of age on learning performance, $F(2, 225) = 69.04$, $MSE = 0.19$, $p < .001$, $\eta_p^2 = .38$. There was no main effect of instruction condition, $F(2, 225) = 1.66$, $MSE = 0.19$, $p = .193$, $\eta_p^2 = .02$ and no interaction, $F(4, 225) = 0.77$, $MSE = 0.19$, $p = .548$, $\eta_p^2 = .01$. Post hoc tests with Bonferroni correction showed that the older adults ($p < .001$), and the children ($p < .001$), performed worse than the young adults, but there was no such difference between the older adults and the children ($p = 1.000$). On time on task spent in the learning phase, results also showed a main effect of age, $F(2, 225) = 87.84$, $MSE = 96.05$, $p < .001$, $\eta_p^2 = .44$, no effect of instruction condition, $F(2, 225) = 2.83$, $MSE = 96.05$, $p = .061$, $\eta_p^2 = .03$, and no interaction, $F(4, 225) = 1.20$, $MSE = 96.05$, $p = .311$, $\eta_p^2 = .02$. Post hoc tests with Bonferroni correction showed that the older adults were significantly slower on problem solving than the young adults ($p < .001$), and the children ($p < .001$), and the children were significantly slower than the young adults ($p < .001$).

Table 7.
Means (and SD) of Learning and Transfer Performance, Time on Task and Mental Effort in all Age Groups

		Type of instruction	No cue (*n* = 83)		Symbolic cue (*n* = 74)		Gesture cue (*n* = 77)	
			M	*SD*	*M*	*SD*	*M*	*SD*
Learning	Performance	Children	0.83	0.40	0.78	0.41	0.84	0.42
		Young Adults	1.45	0.50	1.66	0.45	1.61	0.35
		Older Adults	0.66	0.42	0.85	0.53	0.79	0.47
	Time on task (s)	Children	34.41	9.91	34.28	9.05	31.68	9.30
		Young Adults	17.99	10.95	16.82	9.91	17.60	8.79
		Older Adults	43.70	8.59	38.48	10.64	35.66	10.99
	Mental effort	Children	3.31	1.74	3.29	1.66	3.04	1.90
		Young Adults	2.24	1.42	2.65	1.58	1.85	1.11
		Older Adults	4.42	1.94	3.89	2.12	4.35	1.57
Transfer	Performance	Children	18.97	3.83	19.16	5.28	18.30	4.05
		Young Adults	21.81	3.31	20.18	3.05	22.11	3.20
		Older Adults	16.17	4.15	15.80	4.15	17.36	3.91
	Time on task (s)	Children	15.38	3.80	14.39	4.87	14.74	4.96
		Young Adults	15.75	3.87	15.50	4.32	13.84	5.35
		Older Adults	16.74	4.49	18.33	3.65	17.99	4.34
	Mental effort	Children	2.51	1.78	2.65	1.90	2.57	2.20
		Young Adults	4.36	1.70	4.72	1.87	4.39	1.86
		Older Adults	3.55	2.07	4.09	2.45	4.40	1.93

Note. $N = 234$: children, $n = 92$; young adults, $n = 59$; older adults, $n = 83$.

On transfer performance, results again showed a main effect of age, $F(2, 225) =24.93$, $MSE = 16.31$, $p < .001$, $\eta_p^2 = .18$, but no effect of instruction condition, $F(2, 225) = 0.87$, $MSE =$

16.31, $p = .422$, $\eta_p^2 = .01$ and no interaction, $F(4, 225) = 1.07$, $MSE = 16.31$, $p = .372$, $\eta_p^2 = .02$. Post hoc tests with Bonferroni correction showed that the older adults performed worse than the children ($p = .001$), and young adults ($p = .001$), and the children performed worse than the young adults ($p < .001$).

On time on task in the transfer task, results showed a main effect of age, $F(2, 225) = 10.45$, $MSE = 19.63$, $p < .001$, $\eta_p^2 = .09$, no effect of instruction condition, $F(2, 225) = 0.31$, $MSE = 19.63$, $p = .735$, $\eta_p^2 < .01$ and no interaction, $F(4, 225) = 1.15$, $MSE = 19.63$, $p = .332$, $\eta_p^2 = .02$. Post-hoc tests with Bonferroni correction showed that the older adults were significantly slower in problem solving than the young adults ($p < .001$), and children ($p < .001$), but there was no difference between the children and young adults ($p = 1.000$).

In sum, young adults outperformed the older adults and the children in terms of accuracy and time on task in the learning and transfer tasks, and the children outperformed the older adults on all of these measures, except for learning performance (see Table 7).

Discussion

The aim of the present study was to find out whether the positive effects of gesturing on learning that have previously been found with children and young adults would also apply to older adults. More specifically, we aimed to find out whether gestures in a video-based instruction would improve learning and transfer of a novel problem-solving task in older adults. It was hypothesized that possible benefits on learning would be caused by a modality effect, in that the specific involvement of motor actions would reduce cognitive load and lead to the construction of a richer cognitive schema. To control for the specific effect of the involvement of the motor system, the gesturing condition was not only compared with a non-gesturing control condition but also to a symbolic cueing condition in which arrow cues, instead of gesturing cues, were used to support learners in focusing their attention on the relevant aspects of the task. It was expected that learners in the gesture cue condition compared with the symbolic cue and no cue conditions would show higher learning efficiency. In addition, an interaction effect between type of instruction and task complexity was hypothesized, which means that the benefits of the gesturing condition for learning would be more pronounced in the complex tasks than in the simple tasks.

In contrast to the beneficial effects of gestures on children' and young adults' learning found in previous research (e.g., Ping & Goldin-Meadow, 2008; Valenzeno et al., 2003), the present study yielded no such results; we only found an advantage of gestures compared with no gestures in terms of older adults' time on task. The hypothesis that gesture cues compared with no cues or symbolic cues impose a lower cognitive load and lead to better learning and transfer performance was not supported in any of the age groups. On the contrary, young adults who learned from an instruction without cues performed best on transfer problems and significantly better than those who learned from instruction with symbolic cues.

An explanation for this finding might be found in literature on the expertise reversal effect (Kalyuga, Ayres, Chandler, & Sweller, 2003), the effect that more knowledgeable learners might suffer from an instruction meant for novices. Because all young adult participants were University students and familiar with participating in experiments, they might have been more 'knowledgeable' learners than the children and older adults and that their learning hampered in the symbolic cue condition because of an 'expertise' reversal effect. A second explanation is that an arrow on screen might have induced a redundancy effect (Mayer & Moreno, 2003), which is the negative effect on learning that can occur if the same information is presented in two modalities at the same time. In combination with the expertise reversal effect, a redundancy effect may have occurred because the young adults did not need any cue for learning and that particularly the redundant arrow cue might have caused unnecessary distraction. The question remains, however, why no such redundancy effect applied to gesture cues; a potential explanation is that gestures are automatically integrated and processed with speech (Kelly et al., 2010) and therefore do not require additional resources from the learner.

In terms of time on task, there was no effect of instruction for children and young adults. However, the gesture cue compared with no cue instruction led to significantly faster isomorphic problem-solving performance in older adults. These time on task results appear to be consistent with the results obtained by Laurienti et al. (2006). They also found speeded responses in older adults in reaction to multimodally compared with unimodally presented information. Although this difference was found in a simple target detection task, the present study suggests that an advantage of multimodally over unimodally presented information on time on task might also apply to more complex problem-solving tasks. Furthermore, Laurienti et al. stated that sensory encoding is more prone to noise, and sensory attention has changed in older adults. Linking this to our findings, it can be assumed that a multimodal speech–gesture instruction speeds up subsequent performance because crucial task features are made more salient by gestures and because gestures timely guide attention to relevant features throughout the instruction.

As expected, it was found that all age groups performed better on simple than complex problems in both learning and transfer performance. Second, all age groups showed higher mental effort for the complex than the simple problems on learning performance and for the children and young adults on transfer performance. This finding provides evidence for the sensitivity of our measures to variations in complexity and cognitive load. Similarly, looking at age effects, we found, as expected, that young adults outperformed the older adults and the children, and the children outperformed the older adults. These findings underscore that the search for learning gains from instructional design is especially important for older adults.

A problem of the present study is that it possibly restrained variability in accuracy and time on task. The learning and transfer test both had a fixed amount of problems with a maximum amount of time per problem. From the present data, it seems that participants in our three conditions performed equally well in terms of accuracy, but differed in terms of time on task in that the gesture group was faster than the no cue group. This poses the question of what performance accuracy would have looked like if participants all had to work a fixed amount of time on an infinite amount of problems. An interesting question to consider in future research would be, for example, whether a gesture group would solve more problems than a no cue group when both groups are given the same amount of time?

Besides the findings that older adults who learned from a gesture cue instruction solved isomorphic problems faster than those learning from a no cue instruction (moderate effect size of $\eta_p^2 = .11$), no evidence in favor of the use of gesture cues was found in this study. Effect sizes for the comparisons of the instruction conditions were small. Altogether, no straightforward conclusions on the effect of gesture cues can be drawn based on the present findings.

In contrast to all the findings showing a positive effect of gestures on learning, the present study does not show an effect of gestures at all. An interesting idea for future research would be to replicate earlier studies that did find a positive effect of gestures on children's and young adults' learning and add a sample of older adults for comparison. Although we cannot formulate instructional design guidelines based on the present study, and despite the lack of hypothesized effects, we do feel that the present study adds important information to the literature. First, to the best of our knowledge, this is the first study investigating the influence of gestures on problem solving in children, young adults, and older adults. Our problem-solving paradigm was sensitive enough to detect an effect of age showing that young adults outperformed children and children outperformed older adults. Furthermore, all age groups had performed better and experienced less mental effort on the simple versus the complex problems, which indicates that our measures were sensitive to variations in complexity and cognitive load. Although our design has proven to be valid in manipulating task complexity and sensitive to detect an effect of age, the results showed almost no effect of gestures, which is not in line with previous studies that did show a positive effect of observing gestures on learning (De Koning & Tabbers, 2013) and problem solving (Lozano & Tversky, 2006). This difference might be caused by the type of task used; De Koning and Tabbers (2013) did not look into problem solving and Lozano and Tversky, (2006) used a more concrete type of problem solving (assembly of a simple object). It is possible that in a more abstract problem-solving task, gestures might not influence learning, which is an interesting question for future research. Second, in addition to most studies comparing the presence or absence of gestures on learning, this study added a symbolic cue condition. Surprisingly, this control condition showed a negative effect of symbolic cues on simple transfer performance in young adults.

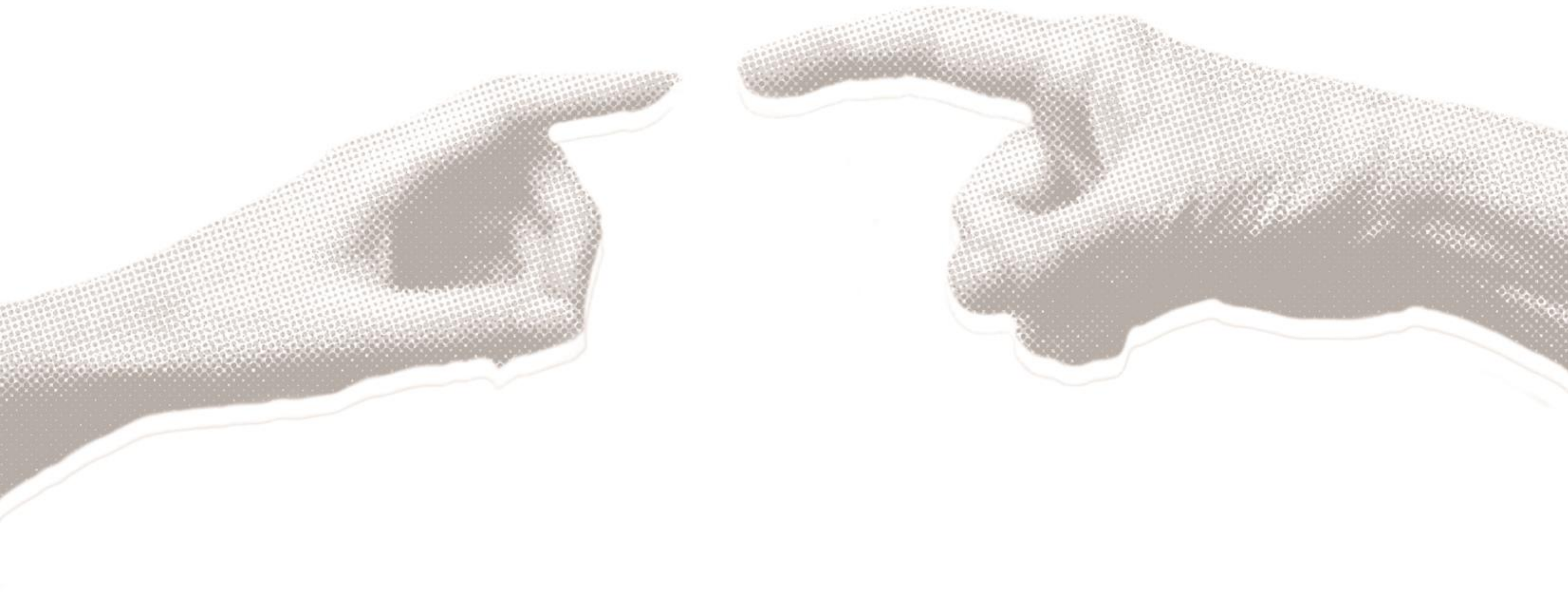
And finally, the few effects we did find raise some interesting questions for future research. The effect of gestures on older adults' time on task on isomorphic problem solving suggests the possibility of gestures in instruction to speed up older adults' problem-solving performance. This finding is interesting to explore in future research, because aging is associated with cognitive slowing and some theorists propose that this slowing is the major underlying mechanism for a broad variety of age-related cognitive declines (for a review see, Salthouse, 1996). The finding that young adults' learning from an instruction with symbolic cueing suffered, compared with those learning from an instruction without any cues, asks for more research to find out when cueing helps or hinders learning and why and which types of cues are suited for which type of task(s) and population(s).

From a practical point of view, research on the effects of gestures in video-based modeling examples is important because such examples are increasingly used by learners of all ages. As mentioned in the introduction, older adults increasingly use the Internet, including online videos to learn how to accomplish certain tasks (Milliken et al., 2012). Little is known about effective design guidelines for such videos, however. Arguably, the differences between young and older adults in terms of age-related cognitive declines might make design guidelines to optimize working memory load and learning even more necessary for older adults. Because research on gesturing has shown beneficial effects on learning other kinds of tasks (e.g., Goldin-Meadow & Wagner, 2005), and because cueing has been shown to reduce cognitive load and foster learning (De Koning et al., 2009; Van Gog, 2014), we expected that an instructor's use of gesture cues might improve learning, particularly for older adults and young children. However, because the present study did not show the expected positive effects of gestures, we can only conclude that gestures neither hampered nor improved learning compared with no gestures or symbolic cues for our problem-solving task. Future research might investigate whether gesturing would be more effective for improving other aspects of older adults' cognition, such as source memory, which is known to decline with age (Bastin & Van der Linden, 2005; Swick, Senkfor, & Van Petten, 2006).

In conclusion, more research is needed to discover under which conditions gestures in video instructions and other kinds of learning materials can improve learning in older adults, a population that might have trouble with existing instructional environments, which are usually tailored to young adults.

Chapter 3

Designing effective video-based modeling examples using gaze and gesture cues



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Abstract

Research suggests that learners will likely spend a substantial amount of time looking at the model's face when it is visible in a video-based modeling example. Consequently, in this study we hypothesized that learners might not attend timely to the task areas the model is referring to, unless their attention is guided to such areas by the model's gaze or gestures. Results showed that the students in all conditions looked more at the female model than at the task area she referred to. However, the data did show a gradual decline in the difference between attention toward the model and the task as a function of cueing: students who observed the model gazing and gesturing at the task, looked the least at the model and the most at the task area she referred to, while those who observed the model looking straight into the camera, looked most at the model and least at the task area she referred to. Students who observed a human model only gazing at the task fell in between. In conclusion, gesture cues in combination with gaze cues effectively help to distribute attention between the model and the task display in our video-based modeling example.

Introduction

Over the past decade, learning from videos in which a human model demonstrates and (often) explains how to complete a certain task, has rapidly gained popularity, both in formal and informal educational settings (e.g., YouTube). Such so-called video-based modeling examples provide an opportunity for example-based learning, which is a very effective type of instruction, especially for novice learners (for a review, see Van Gog & Rummel, 2010). However, video-modeling examples come in many forms, and little is known about design characteristics that make such examples effective in terms of attention guidance and learning (Van Gog & Rummel, 2010). For instance, in video examples in which the model is standing next to a whiteboard or smartboard on which the learning task that the model is explaining is visualized (a typical modern classroom situation), it is possible that the presence of the model creates a type of split-attention effect. The split-attention effect is the adverse effect on learning that is found when students have to mentally integrate information from multiple sources (Ayres & Sweller, 2014). On the other hand, gaze direction and pointing gestures made by the model can automatically trigger attention shifts (Sato, Kochiyama, Uono, & Yoshikawa, 2009). In this way, gaze and gesture cues might be able to timely guide the learners' attention toward relevant aspects of the learning material and thereby alleviate such split attention. The question addressed in the present study is: What do learners attend to in a modeling example in which the model is visible, and can the model effectively guide learners' attention by gazing or gesturing at parts of the task?

The model as a potential source of split-attention

The reason why seeing the model in the video example might evoke a division of attention between the model and the task that the model is referring to, is that people's attention is automatically drawn to other people's faces. There is probably no other object that is looked at as often as the human face, and face perception might well be the most highly developed visual skill in humans, who possess an extensive neural brain circuit involved in face perception and processing (Haxby, Hoffman, & Gobbini, 2000). Moreover, it has been shown that humans prefer to look at faces from a very young age (Tzourio-Mazoyer et al., 2002)

In a study by Gullberg and Holmqvist (2006), in which observers had to listen to and recall an event described by a visible speaker, it was shown that observers focused primarily on the speaker's face. Eye tracking was used to investigate the amount of viewing time spent looking at a speaker's face in three conditions: (1) the speaker was telling about the event directly to the addressee, (2) a video (recorded in condition 1) of the speaker was presented at life-size or, (3) that same video was presented on a 28 inch TV screen. Results showed that over 90% of viewing time was spent looking at the speaker's face (95.6%, 94.2% and 90.8% in condition 1, 2, and 3 respectively). Although observers had to recall the event the speaker talked about, the speaker did not demonstrate a task, so this study did not investigate how we attend to human modeling examples in which a task is demonstrated and explained to learners.

Even though the findings reviewed above suggest that the model's face is likely to receive a substantial amount of attention, it is unlikely that learners would look at the model 90% of the time, since they know they have to observe the demonstration and will be tested on their ability to perform that task themselves later on. Indeed, in a recent study using video-based modeling examples in which it was demonstrated how to solve a puzzle problem by manipulating objects (the model was seated behind a table; the puzzle's objects were placed on the table), half of the participants saw a version of the example in which the face of the model was visible and the other halve saw a version of the same example in which the face of the model was not visible. Learners who saw the example video in which the model's face was visible, were found to look at the model's face only about 20% of the time, but they outperformed those who did not see the model's face, after observing the example twice (Van Gog, Verveer, & Verveer, 2014). These findings suggest that the attention allocated to the model does not have to result in a negative effect on learning, and that learners are quite able to efficiently divide their attention between the model and the task.

It should be noted though, that in demonstrating this puzzle problem-solving task, the model was gazing at, gesturing at, and manipulating physical objects. This is very different from lecture-style modeling examples in which a model is standing next to a whiteboard on which slides illustrating the steps in the problem-solving procedure are projected and advanced by the model clicking a remote. In such examples, if the model continues to look into the camera, there might be a higher risk of split-attention, because learners have to visually search on the screen what the model is talking about, which imposes unnecessary cognitive load during learning (Wouters, Paas, & Van Merriënboer, 2008). Furthermore, when learners are looking at the model's face, they might not attend timely to the task areas the model is referring to, which might result in a) problems integrating the model's explanation into a coherent mental model of the task, and b) not noticing certain changes in the problem-solving states shown in the slides, especially if the information shown in the slides is transient (i.e., prior steps are no longer visible after each new step/slide is presented; see Sweller, Ayres, & Kalyuga, 2011, on the transient information effect). The question is then, whether we would indeed find evidence that learners may have trouble attending timely to the relevant aspects of the task, and whether gaze cues and gesture cues could help to efficiently guide learners' attention through such lecture-style video-based modeling examples.

The model's gaze and gestures as attention guiding cues

In an instructional setting, making deictic gestures (pointing and tracing gestures) has been found to enhance learning (Macken & Ginns, 2014). We suggest that deictic gestures made by a video-based model can function as cues to direct learners' attention toward relevant aspects of the task on crucial moments during the instruction. Research has shown that our attention to faces mainly focuses on the eyes (Vecera & Johnson 1995) and that eye gaze is a powerful attentional cue; we tend to automatically follow other people's gaze in order to look at what they are looking at (for reviews see Birmingham & Kingstone, 2009; Langton, Watt, & Bruce, 2000). Indeed, even though the aforementioned study by Gullberg and Holmqvist (2006) showed that in general, speakers' gestures were hardly fixated at all (less than 1%); observers did relatively often fixate on those gestures that the speakers looked at themselves.

The fact that gestures were hardly fixated in the Gullberg and Holmqvist (2006) study (although it is possible that the gestures were processed through peripheral vision) is quite surprising, because gestures fulfil an important communicative function. For instance, gestures have been found to improve learning (because they capture and guide attention; Valenzeno, Alibali, & Klatzky, 2003) and can communicate information not conveyed in speech (Singer & Goldin-Meadow, 2005). In animations in which a humanoid pedagogical agent gave explanations of the learning content, Mayer and DaPra (2012) found an embodiment effect, indicating that animated agents producing humanlike behavior, such as emotional expression, biological movement, gestures and eye gaze, led to better learning outcomes. This effect has also been found with animated pedagogical agents (Moreno, Reislein, & Ozogul, 2010). Moreno et al. (2010) compared learning from a narrated animation with (1) an animated pedagogical agent that produced pointing gestures toward key aspects of the learning material, (2) the same animation in which the gestures were replaced with arrow cues, and (3) static visualizations. They found that instruction with a gesturing pedagogical agent, led to superior learning compared to instruction using a non-gesturing agent or static visualizations.

Furthermore, research has shown that gestures accompanying speech are perceived as an integrated whole with speech (Kelly, Creigh, & Bartolotti, 2010), and processed in parallel with the head and eye movements (Langton et al., 2000) they accompany. In sum, these results suggest that both gaze and gesture cues are automatically processed and integrated with speech (i.e., quite effortlessly, without imposing much working memory load). These cues might therefore be very useful in video-modeling examples to ameliorate the potential effects of the model's presence as a source of split-attention, by guiding the learners' attention efficiently through the examples.

The present study

The present study investigated this assumption by measuring learners' visual attention allocation toward the model and the task aspects in the slides that the model was referring to in her verbal explanation. Participants watched a video-based modeling example showing a human model verbally explaining a novel problem-solving task and either looking straight into the camera (no cue condition), or making occasional gaze shifts toward specific task areas on the screen (gaze cue condition), or making occasional gaze shifts accompanied by pointing gestures toward the screen (gesture + gaze cue condition; see Figure 1 for an impression).

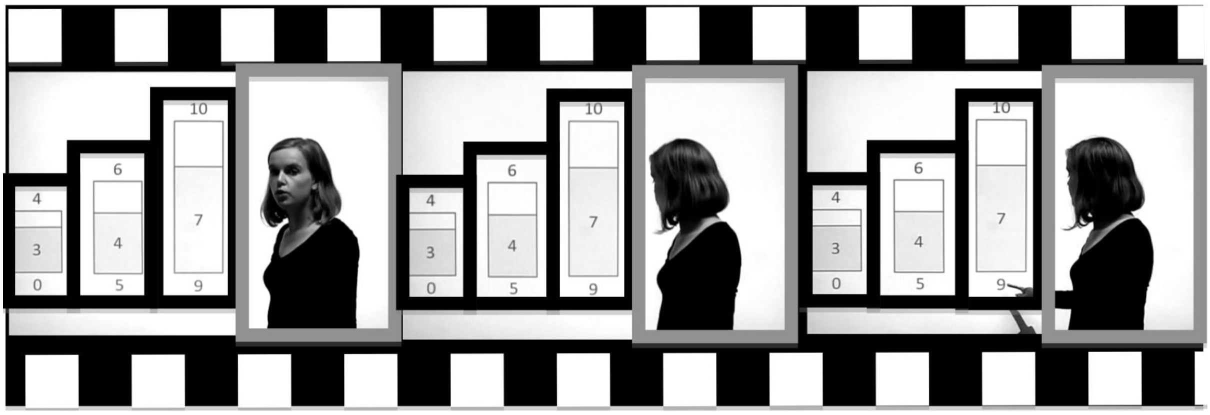


Figure 1. Snapshot of each of the three video-instruction conditions, from left to right: no cue, gaze cue and, gesture + gaze cue condition, displaying the AOI's for the model (the gray lined AOI) and the task (the black-lined AOI's). The model is explaining an example of a water redistribution problem. The goal amount is represented in the numbers under and, the maximal amount by the ones above the jugs, and the current amounts by the numbers in the jugs.

For those scenes of the video-modeling example in which the model was referring to a specific part of the task on the screen (i.e., the small, medium, or large jug), we investigated how learners' attention allocation (fixation time) was distributed between the model and the task area referred to in that scene. In the scenes in which the model was referring to one of the jugs, students should ideally spend a substantial proportion of time looking at that task Area of Interest (AoI) instead of looking at the model, and cueing might assist them in shifting their focus to the task AoI, with gesture cues being more specific than gaze cues.

It was therefore hypothesized that participants in the no cue condition would spend more time looking at the model and less at the task AoI than those in the gaze cue condition, who would in turn spend more time looking at the model and less at the task AoI than those in the gesture + gaze cue condition. In addition, it was expected that the distribution of attention between the model and the relevant task (screen) areas would be least optimal in the no cue (split-attention) condition, more optimal in the gaze cue condition, and most optimal in the gesture + gaze cue condition. That is, learners in the no cue condition would first have to process what the model was talking about, then shift their attention toward the screen and then search the information on the current slide to determine the right task area, by which time the model might already be at a next step. In the gaze cue condition, distributing attention should be more optimal, because the model's gaze shift toward the screen would automatically induce an attention shift of the learners, meaning they would look less at the model. However, they might not look more at the task AoI, because they would still have to search for the relevant task area on the current slide as this might not be obvious. This visual search is prevented in the gesture + gaze cue condition, in which attention is not only automatically drawn to the screen, but also to the right aspect of the task on the current slide, which should therefore lead to the most optimal distribution of attention.

Besides visual attention, participants' performance and invested mental effort on subsequent isomorphic and transfer problem solving was measured to explore whether optimal attention distribution would also lead to optimal performance and mental effort.

Method

Participants and design

Participants were 35 Dutch undergraduate Psychology students who participated for course credits. All participants had normal or corrected-to-normal vision. Despite successful calibration, one participant had to be excluded due to too much missing eye tracking data, leaving a sample of 34 participants for analysis (20 women, 14 men, M_{age} = 22.7 SD = 2.0, age range: 20–28).

Participants were randomly assigned to one of three video-based modeling example conditions. In all conditions participants studied videos of a human model standing next to a screen displaying the problem-solving task, while verbally explaining and demonstrating the solution procedure that was illustrated by a series of slides projected onto the screen. Depending on the assigned condition, the model either (1) made no gestures or gaze shifts and looked into the camera while talking (i.e., no-cue), (2), made no gestures, but occasionally looked at relevant task areas on the screen when these were being mentioned (i.e., gaze cue), or (3) looked at and made pointing and tracing gestures toward the relevant task areas on the screen when these were being mentioned (i.e., gesture + gaze cue). Figure 1 provides an illustration of each condition.

Materials

Problem-solving tasks and video-based modeling examples. The problem-solving task consisted of an adapted version of the water redistribution paradigm from Schmid, Wirth, and Polkehn (2003), which is based on Luchins' (1942) water jug task. Participants were presented with three jugs with a certain maximum content (displayed above each jug) containing certain amounts of water (inside each jug), which they were instructed to redistribute until a goal state (displayed below each jug) would be reached (see Appendix 1 for an example). Problem solving was constrained by one task rule: The entire content of the donating jug would always be emptied into the receiving jug (i.e., no partial contents could be redistributed), unless the receiving jug would not have enough capacity for the content of the donating jug, in which case the receiving jug would be filled to the brim, leaving the donating jug with the residual. The problems used for the present experiment consisted of three-step water redistribution problems that could only be solved with a counterintuitive strategy. Carder, Handley, and Perfect (2008) explain the counterintuitive strategy with the evaluation factor (EVF), which is the sum of differences between the current and goal states of all jugs. For example, in Figure 1, the EVF is 6 (3 + 1 + 2). A step that decreases the EVF is called perceptually consistent, because it directly brings the problem solver perceptually closer to the goal state. A counterintuitive step increases the EVF, but is sometimes a necessary step in the solution pathway. Hence, problems that should be solved with a counterintuitive strategy requires problem solvers to look more than one move ahead (Bull, Espy, & Senn, 2004) and are therefore more demanding for working memory than problems that can be solved with a perceptually consistent strategy (Carder et al., 2008).

A computerized version of this water redistribution task (Schmid et al., 2003) was created in E-prime 2.0. Participants could redistribute water through mouse clicks on the jugs. In Figure 1, for example, in order to pour water from jug A into jug B, participants first had to click on the jug they wanted to pour water from (i.e., the donating jug, in this case A; the water in this jug changed to a darker color as a visual confirmation that it was selected) and secondly, on the jug they wanted to pour water into (i.e., the receiving jug, in this case B). With the second click, the water levels of the jugs changed according to the task rule.

For each condition, a video-based modeling example was created, in which the same female model explained a problem-solving task while standing next to a screen depicting the task (a typical lecture situation). In all three conditions, the model gave the same verbal explanation (see Appendix 1). The problem state depicted on the slide that was projected on the screen changed automatically to the next problem state (i.e., slide) when the model mentioned a problem-solving step being performed, so no interaction of the model with the screen was required. The video-examples in all conditions were divided in 33 scenes, consisting of six scenes in which participants were expected to look at the model (because no task-relevant areas on screen were referred to), and 27 scenes in which the model referred to task-relevant areas. Task-relevant areas were referred to verbally in the no cue condition, verbally combined with simultaneous gaze shifts in the gaze cue condition, or verbally combined with simultaneous gaze shifts and gestures in the gesture + gaze cue condition (see Figure 1).

The video-based modeling examples were recorded with a digital video camera and edited in Final Cut Pro 7.0.3. All videos had the same duration of 120 s and were presented in E-prime 2.0.

Mental effort. After each problem participants rated how much mental effort they invested in solving it, which is an indicator of experienced cognitive load. The mental effort rating scale consisted of labeled values ranging from 0 (no effort) to 9 (extremely high effort) and was adapted from Paas (1992; see also Paas, Tuovinen, Tabbers, & Van Gerven, 2003). The mental effort rating scale was also presented in E-prime 2.0 and participants responded by pressing a number on the keyboard that corresponded to the amount of mental effort they invested in the task.

Eye tracking equipment. The video-based modeling examples and problem-solving tasks were presented in E-prime on the 21-inch display of a Tobii 2150 (50 Hz) eye-tracker, which registered participants' eye movements while they studied the modeling examples. Participants sat approximately at a 70 cm distance from the screen. To show the videos full screen they were presented with a 600 x 800 resolution. The system was recalibrated in IView prior to each example, with a 5-point calibration.

Procedure

The experiment was conducted in individual sessions of approximately 15 min. Participants first read a short written instruction about the basic task rules, for which they received a fixed amount of time of maximally three min. Subsequently, the system was calibrated and participants were instructed to sit as still as possible while they studied the modeling example for the first time. They were then presented with an isomorphic problem to solve (during which they could move freely) after which they rated how much mental effort they invested in solving that problem. After this, participants studied the modeling example for the second time. They were then presented with a new isomorphic problem to solve (during which they could move freely) after which they rated how much mental effort they invested in solving that problem. Finally, participants were presented with two transfer problems, in which the same procedure could be used to solve the problem, but the jugs had different positions, so participants could not just copy the procedure exactly as they observed it. Each transfer problem was followed by the mental effort rating scale. Participants received a maximum of one min to solve all of the problems presented during the experiment.

Data analysis

Eye movement data. The video examples were divided into 33 scenes. There were two types of scenes. In six scenes the main Area of Interest (AoI) was the model (if she was providing explanations not directly referring to the task) and in 27 scenes the main AoI was a part of the task, that is one of the three jugs (with the accompanying numbers above, in and under the jug) that the model was referring to either verbally only, verbally with gaze shifts or verbally with gaze shifts and gestures (see Figure 1). Fixations were defined as gaze points that fell within a radius of 30 pixels and together had a duration of more than 60 ms, and for each AoI in each scene, fixation duration was calculated. Fixation duration on the model and fixation duration on the relevant task area in each scene (i.e., the area being referred to by the model in that scene, which could vary across scenes) were summed only for those 27 scenes in which the task area was the main AoI, and subsequently transformed into a percentage of total fixation duration on those scenes.

Learning outcomes. For each isomorphic problem solved, a performance score was computed by dividing the number of steps in the shortest possible solution (i.e., three), by the actual number of steps a participant took to solve the problem. For example, if participant A solved a three-step problem in three steps and participant B solved the same problem in 15 steps, this would result in a score of 1 for A and 0.2 for B. The same formula was applied for transfer performance, but here, one score was obtained by determining the average performance score over the two transfer problems.

Results

Eye movement data

Table 1 shows the means and standard deviations for the fixation duration (percentage) on the model, on the task areas she referred to (averaged across scenes; hereafter called relevant task area), and on the remaining task areas (averaged across scenes).

Table 1.
Means (and SD) of Fixation Duration as a Percentage of Total Fixation Duration in Task Scenes (i.e., the 27 Scenes in which the Model Referred to a Task Area)

		No cue (n = 11)		Gaze cue (n = 12)		Gesture + Gaze cue (n = 11)	
Time	Object of Attention	*M*	*SD*	*M*	*SD*	*M*	*SD*
1	Model	45.86	17.59	33.72	13.67	29.40	10.30
	Relevant Task Area	12.81	6.18	17.94	6.96	17.90	13.55
	Remaining Task Areas	24.76	8.47	25.23	9.70	23.63	5.47
	Other	16.57	9.05	23.10	11.69	29.07	16.14
2	Model	40.75	23.15	35.17	12.34	26.96	9.95
	Relevant Task Area	15.01	10.56	16.77	7.39	20.07	9.86
	Remaining Task Areas	24.77	11.04	24.99	9.70	21.61	5.47
	Other	19.47	10.01	23.07	14.26	31.37	14.23

Note. Fixations on “other” areas are fixations to white space above, below, or next to the task and the model.

Because the overall data include those scenes in which the model did not refer to aspects of the tasks, the data from the task scenes only are more relevant for our hypothesis, and these were analyzed with a 3 x 2 x 2 ANOVA with instruction condition (no cue, gaze cue, or gesture + gaze cue) as between-subjects factor and object of attention (model vs. task) and time (first example vs. second example) as within-subjects factors.

The analysis showed no main effect of instruction condition, $F(2, 31) = 1.51$, $MSE = 184.07$, $p = .236$, $\eta_p^2 = .09$, or time, $F(1, 31) = 0.24$, $MSE = 33.55$, $p = .629$, $\eta_p^2 < .01$, a main effect of object of attention, $F(1, 31) = 39.08$, $MSE = 299.28$, $p < .001$, $\eta_p^2 = .56$, and an interaction between object of attention and instruction condition, $F(2, 31) = 3.81$, $MSE = 299.28$, $p = .033$, $\eta_p^2 = .20$ (see Figure 2). There was no interaction of instruction condition and time, $F(2, 31) = 0.24$, $MSE = 33.55$, $p = .786$, $\eta_p^2 = .02$, object of attention and time, $F(2, 31) = 0.63$, $MSE = 129.85$, $p = .343$, $\eta_p^2 = .02$, or instruction condition, time and object of attention, $F(2, 31) = 0.59$, $MSE = 129.85$, $p = .560$, $\eta_p^2 = .04$.

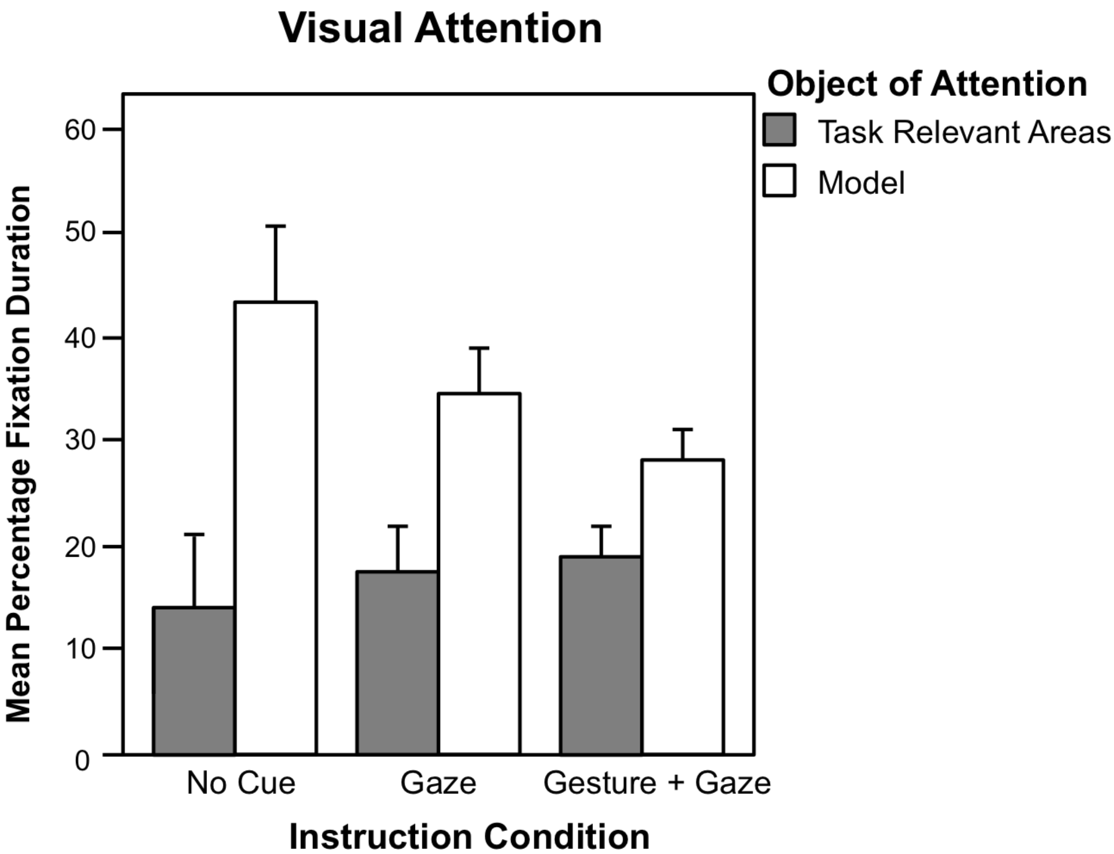


Figure 2. Interaction effect between instruction condition and object of attention.
Error bars represent standard errors + 2 SE.

We followed up on the significant Instruction Condition x Object of Attention interaction with multiple comparisons between instruction conditions on the attention distribution between model and task-relevant areas. We calculated a measure of attention distribution by subtracting the total fixation duration toward task-relevant areas from the total fixation duration toward the model. Results show a significant difference between the no cue and the gesture + gaze cue group, $t(20) = 2.57$, $p = .023$, $d = 1.10$, but no difference between the no cue and gaze cue group, $t(21) = 1.48$, $p = .153$, $d = 0.61$, or the gaze cue and gesture + gaze cue group, $t(21) = 1.47$, $p = .157$, $d = 0.62$. These results indicate that participants in the gesture + gaze cue group had a smaller attentional bias toward the model compared to the task-relevant areas than participants in the no cue group. Figure 2 depicts the interaction between instruction condition and object of attention.

Learning outcomes

Table 2 shows the means and standard deviations of the performance and mental effort data on the isomorphic and transfer problems. Performance and mental effort measures of isomorphic problem solving were analyzed by 3 x 2 mixed ANOVAs with type of instruction (no cue, gaze cue, or gesture + gaze cue) as between-subjects factor and time (problem solving after the first and second time participants watched the video) as within-subjects factors. Performance and mental effort measures of transfer problem solving were analyzed by ANOVAs with type of instruction (no cue, gaze cue, or gesture + gaze cue) as between-subjects factor.

Table 2.
Means (and SD) for Learning and Transfer Performance, and Mental Effort

		No cue (*n*= 11)		Gaze cue (*n*= 12)		Gesture + Gaze cue (*n*= 11)	
		M	*SD*	*M*	*SD*	*M*	*SD*
Performance*	First time	0.42	0.51	0.50	0.52	0.10	0.32
	Second time	0.81	0.39	0.90	0.29	0.65	0.46
	Transfer	0.69	0.46	0.65	0.44	0.49	0.48
Mental effort	First time	5.33	3.39	4.50	3.75	7.00	2.49
	Second time	3.17	2.69	2.83	2.59	4.10	2.96
	Transfer	3.75	3.00	3.54	3.05	4.35	3.23

Note. * For each problem solved, performance and transfer scores were obtained by dividing the minimal amount of steps with which the problem should be solved by the total amount of steps participants made.

Isomorphic problem-solving performance and mental effort. For performance, results showed no main effect of instruction condition, $F(2, 31) = 2.86$, $MSE = 0.23$, $p = .072$, $\eta_p^2 = .16$, a main effect of time, $F(2, 31) = 26.21$, $MSE = 0.13$, $p < .001$, $\eta_p^2 = .46$, but no interaction, $F(2, 31) = 0.53$, $MSE = 0.13$, $p = .595$, $\eta_p^2 = .03$. The analysis of mental effort invested in solving the isomorphic problems showed no main effect of instruction condition, $F(2, 31) = 1.66$, $MSE = 12.25$, $p = .208$, $\eta_p^2 = .10$, a main effect of time, $F(1, 31) = 13.80$, $MSE = 6.08$, $p = .001$, $\eta_p^2 = .31$, but no interaction, $F(2, 31) = 0.45$, $MSE = 6.08$, $p = .643$, $\eta_p^2 = .03$. As Table 2 shows, these results reflect improved performance and decreased mental effort on problem solving after the second compared to the first example.

Transfer problem-solving performance and mental effort. Results showed no main effect of instruction condition on transfer performance, $F(2, 31) = 1.35$, $MSE = 0.20$, $p = .275$, $\eta_p^2 = .08$, or mental effort invested in solving the transfer problems, $F(2, 31) = 0.54$, $MSE = 9.33$, $p = .588$, $\eta_p^2 = .03$.

Discussion

The present study focused on the question of whether gaze and gesture cues would improve the distribution of visual attention when studying a video-based modeling example in which a human model explained how to solve a novel problem. The data show a clear trend in line with our hypothesis that students looked more at the model than at the task-relevant AoI, and that gaze and gesture cues can help shift attention from the model to what she is talking about; students in the no cue condition, looked most at the model and least at the task, while students in the gesture + gaze cue condition looked most at the task and least at the model compared to the other two instruction conditions, and the gaze cue condition falling in between. Thus the attention toward the model gradually decreased and the attention toward the task gradually increased from the no cue, to the gaze cue to the gesture + gaze cue condition. Or in other words, participants who learned from a human model that occasionally gestured and gazed toward the task screen had a smaller attentional bias toward the model compared to the task-relevant areas than participants that learned from a model that did not gesture or gaze at the task.

Our main focus in this study was on the effect of gaze and gesture cues on learners' visual attention distribution, but we also explored whether instruction condition affected learning outcomes, although, in contrast to the eye movement data, for the performance and mental effort data this sample size was probably too low to have sufficient power to detect possible differences. Indeed, we found no significant effects on learning outcomes as measured by performance and perceived mental effort invested in the isomorphic and transfer problems. Because it is a likely assumption that students who spent more time looking at the model than at what the model is talking about would not be able to smoothly integrate the visual and verbal information provided in the example and that this would hamper their learning (see also Mayer & DaPra, 2012; Moreno et al., 2010), future research should replicate this experiment with larger sample sizes in order to address the question of whether better distribution of visual attention between the model and the task-related areas she is referring to, would indeed improve learning.

In sum, this study confirmed that when learning from videos, the model's face attracts a substantial amount of learners' attention, and showed that providing cues, gestures in particular seem effective in redirecting learners' attention from the model to the task areas the model is referring to. Given that the use of lecture-style online instructional videos is rapidly increasing, these findings contribute toward the development of design guidelines for such videos.

Chapter 4

Effects of pointing compared with naming and observing during encoding on item and source memory in young and older adults

The experiments reported in this chapter have been published in: Ouwehand, K., Van Gog, T., & Paas, F. (2015). Effects of pointing compared with naming and observing during encoding on item and source memory in young and older adults. *Memory.* Advance online publication. doi:10.1080/09658211.2015.1094492. The published manuscript additionally contains data from a pilot study as well as a third experiment.

Abstract

Research showed that source memory declines with aging. Evidence suggests that a multimodal encoding strategy, using a motoric-perceptual strategy (i.e., manual pointing and visual observation) compared with unimodal encoding (visual observation only) can have a positive effect on spatial memory. The present study investigated whether pointing at picture locations during encoding, would lead to better spatial source memory than naming (Experiment 1) and visual observation only (Experiment 2) in young and older adults. Experiment 1 supported the hypothesis that pointing led to better spatial source memory than naming. Experiment 2 showed that pointing at picture locations also led to better spatial source memory than passively observing them. Young adults outperformed older adults on the source memory but not the item memory task in both Experiments 1 and 2. The results suggest that pointing at picture locations can enhance spatial source memory in both young and older adults.

Introduction

Most people are familiar with the experience of knowing that they have seen an item, for example their key chain, but do not remember *where* it was the last time they have seen it. This example illustrates the finding that humans have more trouble remembering the contextual information associated with content information, than with remembering content information in isolation, that is, they have more trouble with source memory, than item memory (Van Petten, Senkfor, & Newberg, 2000). The present study investigated whether source memory for picture locations can be improved by making pointing gestures toward the locations during encoding, in young and older adults.

Source memory and aging

Research showed that source memory performance is often less accurate and more sensitive to aging than item memory performance (e.g., Bastin & Van der Linden, 2005; Bayer et al., 2011; Spencer & Raz, 1995; Swick, Senkfor, & Van Petten, 2006; Trott, Friedman, Ritter, Fabiani, & Snodgrass, 1999). To explain this age-related decline in source memory, Naveh-Benjamin (2000) proposed the associative deficit hypothesis (ADH), which hypothesizes that older adults have a binding problem for integrating different units of information such as content and context information into an associated memory. This hypothesis has been supported in numerous studies (e.g., Bastin & Van der Linden, 2005; Naveh-Benjamin, Guez, Kilb, & Reedy, 2004; Naveh-Benjamin, Hussain, Guez, & Bar-On, 2003). Other evidence showed that increased demands on cognitive control functions, such as attentional processes, during the encoding phase but not the retrieval phase negatively affect source memory performance (Anderson, Craik, & Naveh-Benjamin, 1998). Anderson et al. (1998) compared source memory performance in a full attention condition (single task performance) with source memory performance in a divided attention condition (dual task performance). In the divided attention condition a secondary task was either performed during the encoding or the retrieval phase. Results showed that memory performance suffered from divided attention during encoding, but was hardly affected by divided attention during retrieval. Furthermore, Anderson et al. (2000) showed that young adults' source memory performance in a divided attention condition was comparable with that of older adults in a full attention condition.

Interestingly, cueing attention during encoding seems to enhance source memory in young and older adults. For example, Glisky, Rubin, and Davidson (2001) showed that providing a verbal cue improved source memory in older adults up to the level of young adults. Participants were cued in the form of a question ("do you think this chair fits the room?") during the encoding of content-context associations (chair–room associations). Because source memory is error prone in general, and declines as a function of age, an important question is whether and how it can be improved, especially in older adults.

The studies described above suggest that successful source retrieval depends on the quality of encoding including attentional processes (that seem to decline with aging) during encoding. The present study investigated another possible way to enhance source memory by improving the quality of encoding, namely with gesturing.

Improving source memory with action: effects of enactment and gesturing

Research on the enactment effect has convincingly shown that enacting action phrases compared with listening to them, leads to superior source memory in young (e.g., Engelkamp, 1998; Nilsson, 2000; Zimmer, 2001) and older adults (Feyereisen, 2009). In explaining this effect, Kormi-Nouri and Nilsson (2001) stated that the enactment of an action phrase encodes and stores the elements (the object and the action) in the sentence as an integrated event in memory. Note, that asking people to literally enact activates people to act out or pantomime the sentence, whereas listening is rather passive. Feyereisen (2009) took this possible confound into account and added a third condition to the passive listening and enactment condition. In this third condition, participants observed the experimenter enacting the action phrases with pantomimes. Results showed that passive observation of the experimenter's gestures also led to superior source memory compared with passive listening, and there was no difference between the self-performed and experimenter-performed enactment. Importantly, Feyereisen showed that both young and older adults benefited from enacting or observing the actions.

In their review on the effect of action on memory, Madan and Singhal (2012) suggest that other kinds of gestures (being motor actions) can enhance memory in a similar manner as enactment does. Indeed, evidence showed that producing gestures can also facilitate memory (e.g., Cook, Yip, & Goldin-Meadow, 2010) and learning (for a review see Goldin-Meadow & Alibali, 2013). For example, Cook et al. (2010) found that gesturing during the encoding of action/motion events improved immediate and delayed free recall. In addition, both observing and making gestures seem to activate the motor system (Schippers, Gazzola, Goebel, & Keysers, 2009), which suggests that gesturing can add a motoric component to the memory. In relation to the age-related binding problems, proposed by the ADH (Naveh-Benjamin, 2000), the integrative function of gestures might be especially helpful in improving source memory in older adults.

Note that these studies concern mainly enactment and representational gestures, not deictic gestures (i.e., pointing and tracing used to index locations and movement pathways in space). Moreover, even though gestures are often made in interaction, not all gestures have communicative purposes. Yet even non-communicative and deictic gestures may benefit memory processes. For example, Chu and Kita (2011) showed that during the performance of a mental rotation task, participants who were encouraged to gesture (co-thought gestures) solved more problems than those who were not encouraged but allowed to gesture or those who were prohibited from gesturing. Chu and Kita proposed that these so-called co-thought gestures offload the internal computation (i.e., working memory) processes needed to make the spatial transformations, thereby improving performance. There is some evidence that non-communicative deictic gestures during the encoding of object-location associations can also support working memory processes. For instance, Chum, Bekkering, Dodd, and Pratt (2007) found that pointing at simple figures (e.g., circles) at different locations enhanced visuospatial working memory. In addition, several studies show that deictic gestures of a speaker are used to help focus attention to an object in space or a location in a social situation (Bangerter, 2004; Louwerse & Bangerter, 2005; Peeters, Azar, & Özyürek, 2014).

In summary, adding a motoric code during memory encoding by enactment can enhance source memory (Engelkamp, 1998) in young and older adults (Feyereisen, 2009). Furthermore, adding a motoric code by pointing during encoding can enhance visuospatial working memory (Chum et al., 2007) and help focus attention (Bangerter, 2004; Louwerse & Bangerter, 2005; Peeters, et al., 2014). However, it is important to mention that Feyereisen (2009) compared the enactment condition with a passive verbal (listening) condition, not an active verbal condition. It is possible that the beneficial effects of enactment found by Feyereisen were due to activity as such, rather than specific actions. Moreover, the effect of gestures might depend on the nature of the gestures and the task at hand and the question of whether source memory improves from deictic gestures has not yet been addressed (although there is evidence that deictic gestures may support working memory processes: Chum et al., 2007). Because cognitive and attentional control processes (e.g., Braver & Barch, 2002) decline with aging, which is especially problematic for the encoding phase in source memory tasks (e.g., Anderson et al., 1998, 2000), gesturing during encoding might be a promising tool to enhance source memory, especially for older adults. Therefore, the present study will compare the effects of gesturing (pointing) with an active verbal processing strategy (naming) on young and older adults' item and source memory in Experiment 1.

The present study

To the best of our knowledge, the effect of self-produced deictic gestures (pointing) on spatial source memory in young and older adults has not been investigated yet. Therefore, in the present study, two experiments investigated whether pointing at picture locations would lead to better source memory for these locations than verbally naming (Experiment 1) or only visually observing (Experiment 2) the pictures in young and older adults. Encoding strategies (pointing vs. naming and pointing vs. observation only) were tested within participants.

It was hypothesized that pointing at the picture locations during encoding, would lead to better source memory in both young and older adults compared with naming (Experiment 1) and visual observation only (Experiment 2) of the picture locations. Furthermore, it was hypothesized that because of age-related declines in source memory, positive effects of pointing gestures would be larger in older than in young adults. Overall, it was expected that older adults would perform equally well on item memory as young adults, but would perform more poorly on source memory.

General method

Materials

All materials were computerized, programmed in E-prime 2.0 and presented on a 17-inch ELO touchscreen with a 1024 x 768 resolution, tilted backwards at a visual angle of 30°.

Operation span task. The operation span task (Unsworth, Heitz, Schrock, & Engle, 2005) was administered to obtain a general measure of cognitive functioning. These types of working memory span tasks have been found to predict performance on a wide range of cognitive tasks (Engle, Tuholski, Laughlin, & Conway, 1999; Kane, Bleckley, Conway, & Engle, 2001) and share a large amount of variance among each other indicating they measure the same construct (Unsworth et al., 2005). Although a large body of evidence indicates that older adults show age-related declines in cognitive functioning compared with young adults such as working memory (e.g., Cabeza & Dennis, 2013; Conway et al., 2005), this measure was taken to check whether this was also the case in the present sample and to find out whether operation span performance is a useful covariate for the analyses on item and source memory.

Source memory task. Picture stimuli were 156 colored drawings from a subset of the materials of Rossion and Pourtois (2004).

Procedure

Operation span task. Participants were presented with arrays of letters intermixed with arithmetic problems they had to solve. Each trial started with a letter, followed by a problem, followed by a letter etc. In total 75 letters and 75 problems were presented in trials randomly varying in length from three to seven letter-problem pairs. The task started with a five min training in which participants first practiced the letter- and the problem-solving tasks separately and in the final training phase, together. Then the operation span task automatically followed, which took about 10-15 min to complete. One point was assigned for each letter that was recalled in the correct position in the array, which could result in a maximum score of 75.

Source memory task. The general procedure of the source memory task was roughly the same in Experiments 1 and 2. Participants were tested in individual sessions of approximately 20 min. In total, 156 pictures were used, including the 12 pictures used for the training phase. A sample of 144 pictures was used for the actual experiment consisting of 72 pictures of natural objects (such as animals and plants) and 72 pictures of artificial objects (such as furniture and clothing). However, encoding strategies were manipulated within participants and differed between experiments, as specified below.

Encoding phase. The source memory task started with a short training phase in which participants were familiarized with the procedure of the trials in the encoding and test phases. Of the 144 pictures used, 12 (six natural and six artificial) were used in the training phase. Then the experiment started with the encoding phase. Of the 144 pictures used, 96 (48 natural and 48 artificial) were used in the encoding phase. Each of the 96 encoding trials started with the presentation of an empty quadrant dividing the screen in four areas. Participants were instructed to fixate on a cross that was located at the center of the screen. After 1000 ms, a picture was presented off-center toward the middle of the screen at one of the four locations until a response was detected or until the maximum presentation time of 2000 ms had passed (see Figure 1). In Experiment 1, participants were instructed to categorize the pictures as “natural” or “artificial” by pointing with their index finger at the pictures of one category and naming the location of the pictures of the other category. Naming was done by verbalizing one of the following phrases “top left”, “top right”, “bottom left” or “bottom right”, choosing the phrase that corresponded to the location of each picture. Half of the participants were instructed to point at the “natural” pictures and name the “artificial” picture locations and the other half were instructed to point at the “artificial” pictures and name the “natural” picture locations. In Experiment 2, participants had to categorize the pictures by pointing at or only visually observe the pictures, and again, stimulus-response couplings were counterbalanced between participants.

Reaction times of the pointing responses were recorded by the touchscreen as soon as the participants touched the screen. The verbal responses were made in a microphone positioned next to the participants’ heads and reaction times were recorded as soon as the participants started their verbal response. Accuracy of the pointing response was automatically registered in the E-prime software. Accuracy of the verbal response was logged by the experimenter pressing a “1” for a correct response and “0” for an incorrect response. To control for effects of picture sampling, 3 different sets of 96 pictures were randomly selected for the encoding phase. This resulted in three versions of the same task and the presentation of each version was counterbalanced between participants.

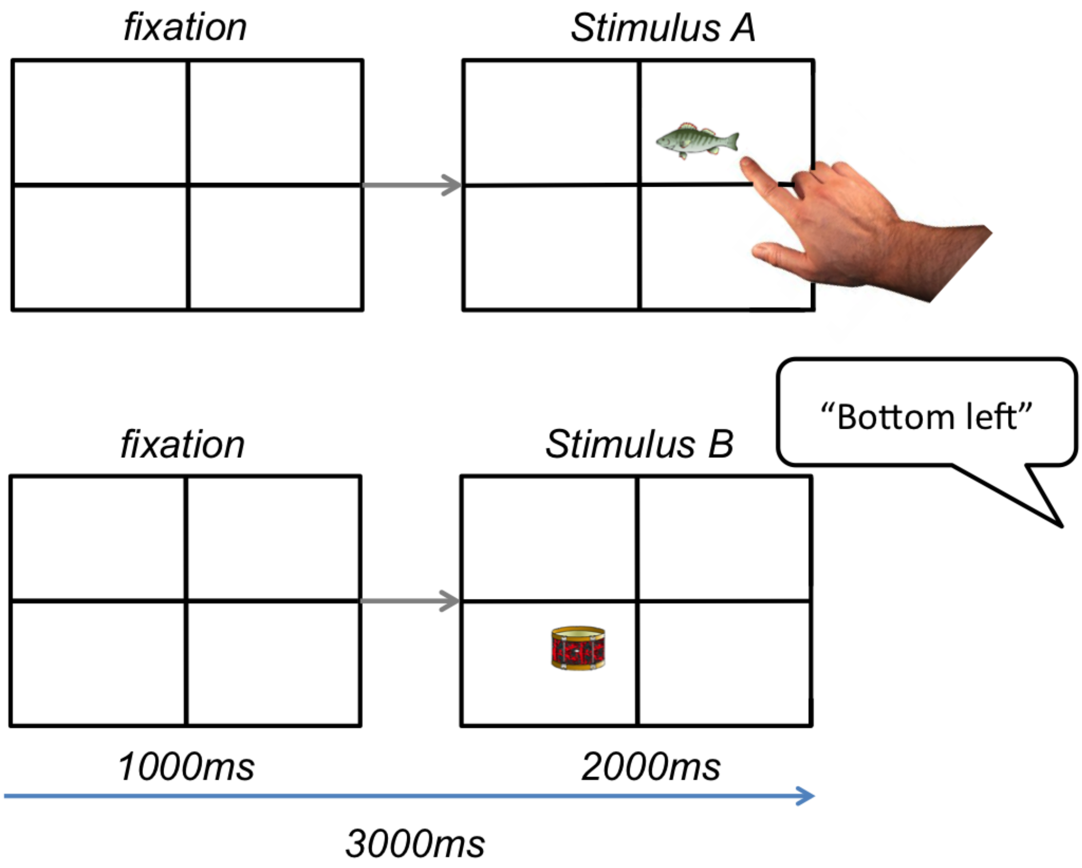


Figure 1. Example of both types of stimulus-response pairs in the encoding phase. In this example, locations of natural pictures (stimulus A) had to be pointed at and that of artificial pictures (stimulus B) named. Stimulus-response couplings were counterbalanced.

Test phase. In the test phase, 144 pictures were shown at the center of the screen. Each trial started with a fixation cross at the center of the screen, which was replaced after 1000 ms by a picture, which was visible for 1000 ms. In both Experiments 1 and 2 participants had to make an old/new judgment deciding whether or not they had seen the picture in the encoding phase by pressing on the word “old” or “new” on the touchscreen as fast and accurately as possible. When participants judged the picture to be “new”, they progressed to a new trial, but when they judged it to be “old”, they were asked to judge at which of the four locations they had seen the picture during the encoding phase. Participants were instructed to make their source judgments as fast and accurate as possible by pressing one of the following words on the touchscreen, “top left”, “top right”, “bottom left”, or “bottom right”, corresponding to the words verbalized in the encoding phase in the naming condition (see Figure 2).

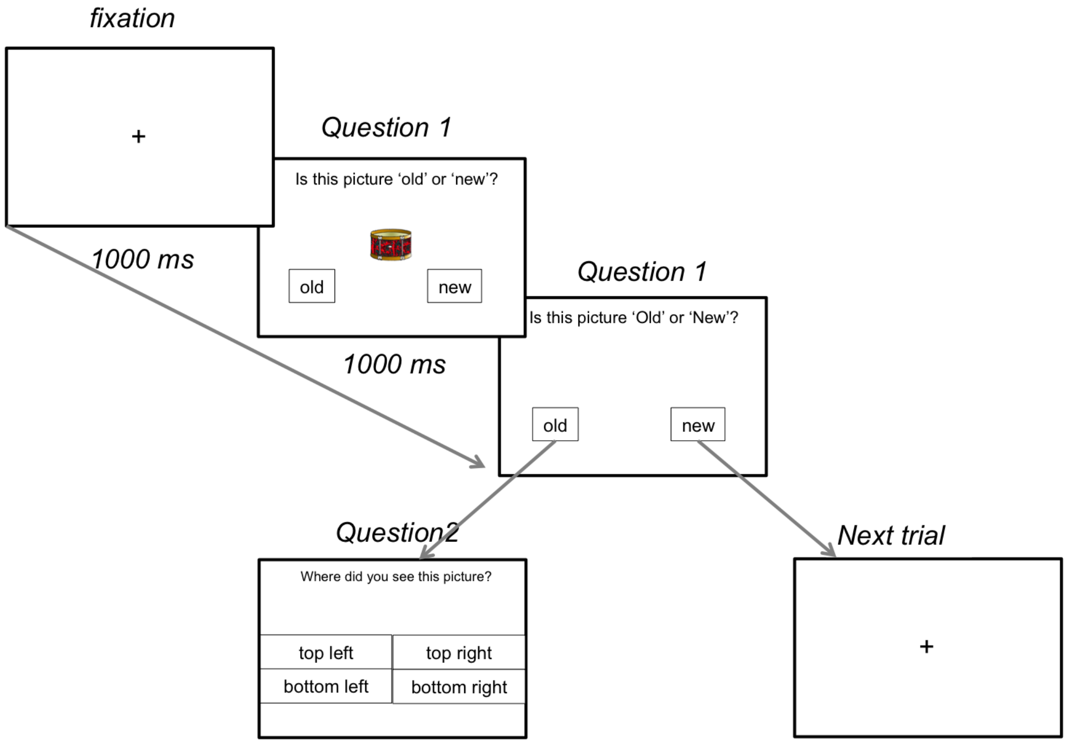


Figure 2. Example of a trial in the retrieval phase.

Data analysis

For both encoding conditions (i.e., pointing and naming in Experiment 1; pointing and observation only in Experiment 2), percentage scores were calculated for item memory, by dividing the total number of correct responses in each condition, by the maximum possible score divided by 100 (i.e., total correct item/ (48/100)). This was also done for source memory by dividing the total amount of correct location judgments by the total amount of correctly recognized items divided by 100 (i.e., total correct source/(total correct item/100)). For the operation span task a performance score was obtained by adding up all the correctly remembered letters in the arrays, which could lead to scores ranging between 0 and 75.

Experiment 1

Participants and design

Participants were 40 young adults and 40 older adults. One young participant was excluded because she was only 16 years old, leaving a sample of 39 participants for analysis (28 women, 11 men, M_{age} = 20.8 years, *SD* = 2.1, age range 18–26), who were all students enrolled at a Dutch university, and participated for course credits. The older adults (24 women, 16 men; M_{age} = 67.0 years, *SD* = 4.2, age range 60–83) were recruited via advertisements in community centers. Advertisements called for healthy older adults (> 60 years of age) and during admission, participants were asked whether they had experienced a stroke (CVA or TIA), dementia, other cognitive problems, or any kind of brain damage or (mild) head trauma in the past. Participants who answered yes to one of these questions were not included in the sample. The older participants received a small monetary reward for their participation. A mixed design with encoding condition (pointing vs. naming) as within-subjects factor and age group (young vs. older adults) as between-subjects factor was used.

Results

Operation span task. An ANOVA showed a significant difference in operation span score between young and older adults, $F(1, 77) = 27.90$, $MSE = 260.50$, $p < .001$, $\eta_p^2 = .27$, with, as expected, operation span in young adults being higher (*M* = 41.11, *SD* = 18.54) than in older adults (*M* = 22.23, *SD* = 13.39).

Correlations between operation span scores and the four dependent variables (item and source memory performance for pointed and named picture locations) were calculated for each age group. No significant correlations were found (see Table 1) and therefore, the operation span scores were excluded from further analysis.

Table 1.
Correlation Matrix of Young and Older Adults' Operation Span Scores with their Item and Source Memory Performance

	Pointing				Naming			
	Item		Source		Item		Source	
Age Group	*R*	*p*	*R*	*p*	*R*	*p*	*R*	*p*
OSpan Young adults	-.09	.596	-.02	.897	.05	.763	.24	.139
OSpan Older adults	.22	.182	-.18	.278	.12	.480	-.09	.567

Note. *N* = 79. Young adults *n* = 39, older adults *n* = 40.

Experimental task

Encoding. Response accuracy for the pointed and named items during the encoding stage was high for both the young adults (pointing, *M* = 97.22%, *SD* = 5.32; naming, *M* =

92.19%, *SD* = 9.99)[1] and the older adults (pointing, *M* = 93.39%, *SD* = 7.52; naming, *M* = 92.14%, *SD* = 8.96). The number of false responses during encoding was low for both the young adults (false pointing in the naming condition, *M* = 0.67%, *SD* = 1.11; false naming in the pointing condition, *M* = 0.69%, *SD* = 1.67) and the older adults (false pointing in the naming condition, *M* = 0.92%, *SD* = 1.09; false naming in the pointing condition, *M* = 0.72%, *SD* = 0.79).[2]

Retrieval. Item and source memory performance and reaction times were analyzed with 2 (encoding condition: pointing vs. naming) x 2 (age group: young vs. older adults) mixed ANOVAs with repeated measures on the first factor. Means and standard deviations of item and source memory performance can be found in Table 2.

Table 2.
Means (and SD) of Young and Older Adults' Item and Source Memory Performance and Reaction Times in Experiment 1

		Young adults				Older Adults			
		Source		Item		Source		Item	
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Pointing	Accuracy (%)	59.71	16.84	71.53	16.62	49.17	15.61	66.98	13.60
	RT (ms)	699	284	937	296	737	321	932	215
Naming	Accuracy (%)	56.36	18.01	65.97	16.32	43.58	13.07	63.28	16.76
	RT (ms)	700	275	951	282	680	253	976	259

Note. *N* = 79. Young adults *n* = 39, older adults *n* = 40.

The analysis of item memory performance also yielded a main effect of encoding condition, $F(1, 77) = 6.04$, $MSE = 139.89$, $p = .016$, $\eta_p^2 = .07$. These results show that item memory performance was higher in the pointing condition than in the naming condition (see Table 2). There was no effect of age group, $F(1, 77) = 1.42$, $MSE = 363.91$, $p = .237$, $\eta_p^2 = .02$, and no interaction, $F(1, 77) = 0.24$, $p = .623$, $\eta_p^2 < .01$. The ANOVA results regarding the reaction times of the item memory judgments revealed no effect of encoding condition, $F(1, 77) = 2.92$, $MSE = 11431.56$, $p = .092$, $\eta_p^2 = .04$, age group, $F(1, 77) = 0.03$, $MSE = 128306.18$, $p = .860$, $\eta_p^2 < .01$, and no interaction, $F(1, 77) = 0.79$, $p = .378$, $\eta_p^2 = .01$.

[1] Note that due to a technical error, the response accuracy for named items was correctly logged for only 16 of the 39 young adult participants, so the percentage correctly named items was calculated only over these 16 participants. However, combined with the data of the pilot test (see appendix 2), there is no reason to doubt that response accuracy was equally high for the other young adult participants as well.

[2] Note that correct and false responses do not add up to 100% because of a small number of misses (i.e., no response before the max. presentation time was up).

The analysis of source memory performance yielded a main effect of encoding condition, $F(1, 77) = 12.26$, $MSE = 64.41$, $p = .001$, $\eta_p^2 = .14$, and age group, $F(1, 77) = 12.04$, $MSE = 445.57$, $p = .001$, $\eta_p^2 = .14$, but no interaction, $F(1, 77) = 0.77$, $p = .383$, $\eta_p^2 = .01$. These results show that source memory performance was higher in the pointing condition than in the naming condition in both age groups (see Table 2). Furthermore, these results show that source memory of young adults was better than that of older adults in both the pointing and naming condition. The analysis of the reaction times of the source memory judgments revealed no effect of encoding condition, $F(1, 77) = 0.87$, $MSE = 34553.36$, $p = .355$, $\eta_p^2 = .01$, age group, $F(1, 77) = 0.02$, $MSE = 127406.27$, $p = .877$, $\eta_p^2 < .01$, or interaction $F(1, 77) = 0.96$, $p = .329$, $\eta_p^2 = .01$.

Discussion

The data supported the hypothesis that pointing toward locations of pictures during encoding leads to better source memory for picture-location associations than verbally naming the locations. And this effect was found for both young and older adults. Overall, older adults had lower source memory performance than young adults. Interestingly, item memory in the pointing condition was also superior to item memory in the naming condition. This finding is further discussed in the General Discussion. No differences between young and older adults were found for item memory performance. This is in line with research showing that with aging, source memory declines are more pronounced than item memory declines (for a meta-analysis, see Old & Naveh-Benjamin, 2008).

The second hypothesis that the effect of pointing on source memory would be larger in older adults than in young adults was not supported; we found no interaction between encoding condition and age group. Although source memory was higher for pointed picture-locations than for named picture locations *within* age groups, young adults had better overall source memory performance than older adults, and older adults did not show a significantly larger difference between the pointing condition and the naming condition than young adults.

In summary, the present experiment showed an advantage in source and item memory performance for picture locations that were pointed at, compared with named. Although the present study showed that pointing during encoding leads to better memory performance compared with a naming strategy, this might not necessarily prove that pointing enhances source memory for locations in general, because in both the naming and pointing condition, participants were required to actively respond to the location of the picture. Therefore, both the naming and the pointing responses might have had some negative effects on encoding, but we were not able to test this assumption in the current experiment. However, pointing might have been more a “natural” response to index a location than the naming. To find out whether or not pointing leads to higher source memory performance than a more neutral condition in which no active response was required, we compared the pointing condition with a condition in which the participants passively observed the pictures in Experiment 2. The results of such an experiment would allow for determining whether pointing really has a positive effect on source memory or that it just has a smaller negative effect than naming. Although this alternative explanation seems unlikely based on the results of previous research showing positive effects of gestures on learning (for a review, see Goldin-Meadow & Alibali, 2013) and memory (i.e., Chum et al., 2007; Wagner-Cook et al., 2010), it is necessary to exclude it before pointing can be identified conclusively as a strategy to improve spatial source memory.

Experiment 2

Experiment 2 used the same materials and procedure as Experiment 1, except for two changes. First, the operation span task was excluded because it did not correlate with the experimental task. Second, the naming condition was replaced with a condition in which participants passively observed the pictures in their locations (observation only condition).

Participants and design

Participants were 32 young adults (21 women, 11 men, M_{age} = 19.8 years, *SD* = 1.5, age range 17–23 years) and 28 older adults (17 women, 11 men, M_{age} = 65.7 years, *SD* = 3.7, age range 60–71 years). The recruitment procedure and reward of the participants were identical to those of Experiment 1. This experiment had a mixed design, with encoding condition (pointing vs. observation only) as within-subjects factor and age group (young vs. older adults) as between-subjects factor.

Results

Encoding. For experimental purposes, the same procedure was used as in Experiment 1 with the only exception that the verbal condition was replaced by an observation only condition. Response accuracy for pointing during the encoding phase was high for both the young (pointing, *M* = 99.41%, *SD* = .01) and the older adults (pointing, *M* = 98.81%, *SD* = .02). The number of false responses during encoding was low (pointing at pictures that should only be observed) for both the young adults (*M* = 0.33%, *SD* = 1.51) and the older adults (*M* = 0.52%, *SD* = 0.92).

Retrieval. Source and item memory performance and reaction times were analyzed with 2 (Encoding Condition: pointing vs. observation only) x 2 (Age Group: young vs. older adults) mixed ANOVAs with encoding condition as the repeated measure. Means and standard deviations of source and item memory performance can be found in Table 3.

The analysis of source memory accuracy yielded a main effect of encoding condition, $F(1, 58) = 11.50$, $MSE < 0.01$, $p = .001$, $\eta_p^2 = .17$, and age group, $F(1, 58) = 10.24$, $MSE = 0.04$, $p = .002$, $\eta_p^2 = .15$, but there was no interaction, $F(1, 58) = 0.69$, $p = .409$, $\eta_p^2 = .01$. These results show that source memory performance was higher in the pointing condition than in the naming condition. Furthermore, it shows that source memory of young adults was better than that of older adults in both the pointing and naming conditions. The ANOVA results of the reaction times of the source memory judgments revealed no effect of encoding condition, $F(1, 58) = 0.12$, $MSE = 29585.17$, $p = .730$, $\eta_p^2 < .01$, a main effect of age group, $F(1, 58) = 40.58$, $MSE = 181072.04$, $p < .001$, $\eta_p^2 = .41$, but no interaction, $F(1, 58) = 0.52$, $p = .473$, $\eta_p^2 < .01$. The main effect of age group reflects the finding that the older adults were slower to make source judgments than the young adults.

The analysis of item memory accuracy, showed no effect of encoding condition, $F(1, 58) = 0.12$, $MSE < 0.01$, $p = .735$, $\eta_p^2 < .01$, age group $F(1, 58) = 0.11$, $MSE = 0.02$, $p = .741$, $\eta_p^2 < .01$, or interaction, $F(1, 58) = 1.45$, $p = .234$, $\eta_p^2 = .02$. Results regarding the reaction times of the item memory judgments revealed a main effect of encoding condition, $F(1, 58) = 48.86$, $MSE = 108973.94$, $p < .001$, $\eta_p^2 = .43$, but no effect of age group, $F(1, 58) = 1.54$, $MSE = 651722.73$, $p = .220$, $\eta_p^2 = .03$, or interaction, $F(1, 58) = 0.07$, $p = .787$, $\eta_p^2 < .01$. The main effect of encoding condition reflects the finding that both age groups were faster to make item recognition judgments for the pointed pictures than the observed pictures.

Table 3.

Means (and SD) of Young and Older Adults' Item and Source Memory Performance and Reaction Times in Experiment 2

		Young adults				Older Adults			
		Source		Item		Source		Item	
Condition		*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Pointing	Accuracy (%)	70.23	13.23	77.60	12.29	57.91	14.96	78.52	11.54
	RT (ms)	578	170	943	469	1097	423	1109	434
Observing	Accuracy (%)	64.55	14.68	78.91	8.99	54.47	15.13	76.19	14.63
	RT (ms)	612	269	1326	752	1085	397	1526	738

Note. $N = 60$. Young adults $n = 32$, older adults $n = 28$.

Discussion

In addition to Experiment 1 showing that pointing at pictures' locations is a better encoding strategy than naming them, Experiment 2 showed that pointing also led to better source memory in young and older adults compared with observation only. These results suggest that pointing to locations during encoding has a positive effect on source memory for picture-location associations.

General discussion

The aim of the present study was to investigate whether or not manual pointing at pictures' locations during encoding could enhance source memory for picture-location associations in young and older adults. In line with our expectations, it was found that a pointing strategy (pointing to pictures locations) led to better source memory than a verbal strategy (naming the pictures' locations) in young and older adults (Experiment 1). Second, our expectation that pointing during encoding would lead to better source memory than observation only in young and older adults was supported in Experiment 2. And as expected, older adults performed equally well as the young adults on the item memory test, but poorer on the source memory test. A surprising finding in Experiment 1 was that item memory performance was better in the pointing condition than in the naming condition. A possible explanation is that naming compared with pointing toward the locations of the pictures was more unnatural. Finding the right words describing the location might have distracted attention away from the encoding of the content of the picture, which resulted in fewer pictures recognized in the item memory test. Note though that this potential drawback of the naming condition could not explain why pointing led to better memory performance, as Experiment 2 demonstrated that pointing also had a beneficial effect compared with observation only.

The present findings are in line with the claim made by Glisky et al. (2001) that source memory performance depends on the conditions under which encoding occurs. Our results also suggest that a simple action such as pointing at a picture location can help the integration of the picture and its location in memory. This is also in line with the account of Kormi-Nouri and Nilsson (2001), who stated that enactment promotes episodic integration, because the action and object that is acted upon are encoded and stored as a single event, and therefore results in better episodic memory. In addition to findings from enactment research showing that enactment or passive action observation compared with a passive verbal condition enhances associative memory (Feyereisen, 2009), the present study also showed that self-produced action in the form of pointing gestures compared with self-produced verbal cues, can lead to superior source memory. This suggests that in the case of associating spatial contextual features to its content during encoding, self-performed pointing cues are superior to self-performed verbal cues.

According to the multimodal theory proposed by Engelkamp (1998), encoding information in more than one modality (for example, by vision and by enactment) can enhance learning. In line with this theory, a possible explanation for the enhanced memory performance for pointed items is that the act of pointing added a motoric memory code and enriched the learner's representation for the picture-location associations. However, in contrast to enactment or pantomimic gestures, that can represent (simulate) specific perceptual and or salient features of learning material, the pointing gestures used in the present study were only specific for the location of the pictures and not for the content of the pictures. Still we found that the picture-location association was stronger for the pictures that participants pointed at during encoding than the pictures of which locations were named or passively observed, even though this action does not represent the content (meaning) of the pictures. This can be explained via attentional processes during encoding. A possible explanation is that the pictures that were pointed at, received more attention than those that were not pointed at (selection-for-action hypothesis, Allport, 1989). An alternative explanation is that pointing toward picture locations is an egocentric and body-based, manner of encoding, compared with observation only, which is a more allocentric and scene-based manner (Chum, et al., 2007), this might make the pictures and their locations more salient and distinctive, which makes them easier to remember later on.

Despite the fact that these explanations are plausible accounts for *why* pointing enhanced source memory performance in our study, they do not explain how this works, in terms of an underlying mechanism. We suggest that neuroscientific research might provide insight into such underlying mechanisms. Several brain imaging studies showed that objects that are only perceived are differently processed than objects we intend to act upon by systems guiding visual attention, namely the dorsal stream for "vision for action" (processing "where" and "how" information important for source memory) and the ventral stream for "vision for perception" (processing "what" information important for item memory; e.g., Boussaoud, di Pellegrino, & Wise, 1995; Goodale & Milner, 1992; Milner & Goodale 2008). Interestingly, a study by Khader, Burke, Bien, Ranganath, and Rösler (2005) showed a specific involvement of the parietal cortex (the projectory site of the dorsal stream) in source memory linking word pairs to locations, but not for linking word pairs with pictures of faces. In explaining our findings, we suggest that in the present study, the pointed pictures might have been processed via the dorsal stream and pictures of which locations were named or only observed via the ventral stream. Because evidence suggests that the parietal cortex might be specifically involved in source memory for locations (Khader et al., 2005), we suggest that this mechanism may also underlie the positive effect of self-produced pointing during the encoding of pictures and their locations. However, caution is required when using this explanation, because we did not use brain-imaging techniques to measure the involvement of the dorsal and ventral stream. Therefore, future research is needed to test this potential explanation by adding neuropsychological evidence to the present behavioral results to investigate the recruitment of the dorsal and ventral areas during encoding and retrieval of pointed compared with named pictures-location associations.

A limitation of the present study is that one could argue that the beneficial effect of pointing might result from transfer appropriate processing (Morris, Bransford, & Franks, 1997) or encoding specificity (Tulving & Thomson, 1973). That is, the appropriateness and overlap of the conditions under which encoding and retrieval occur, can improve memory. All responses in the retrieval phase were made by finger tapping on the touchscreen but only the pictures in the pointing condition, not those in the naming or observation only condition, were tapped during encoding. This overlap in response type in the encoding and retrieval phase in the pointing condition could have enhanced item memory. However, it should be noted that with regard to source memory retrieval, although the response type overlapped with that in the pointing condition, the format of testing overlapped with the naming condition in Experiment 1, in the sense that participants had to choose a word determining the source (e.g., "left top") that they named in the naming condition. In terms of transfer appropriate processing, naming the locations during encoding might have benefited the source memory test, because this test asked participants to choose from the exact words used during encoding in the naming condition. The finding that source memory in the pointing condition was better than in the naming conditions in both age groups in Experiment 1 is therefore even more striking.

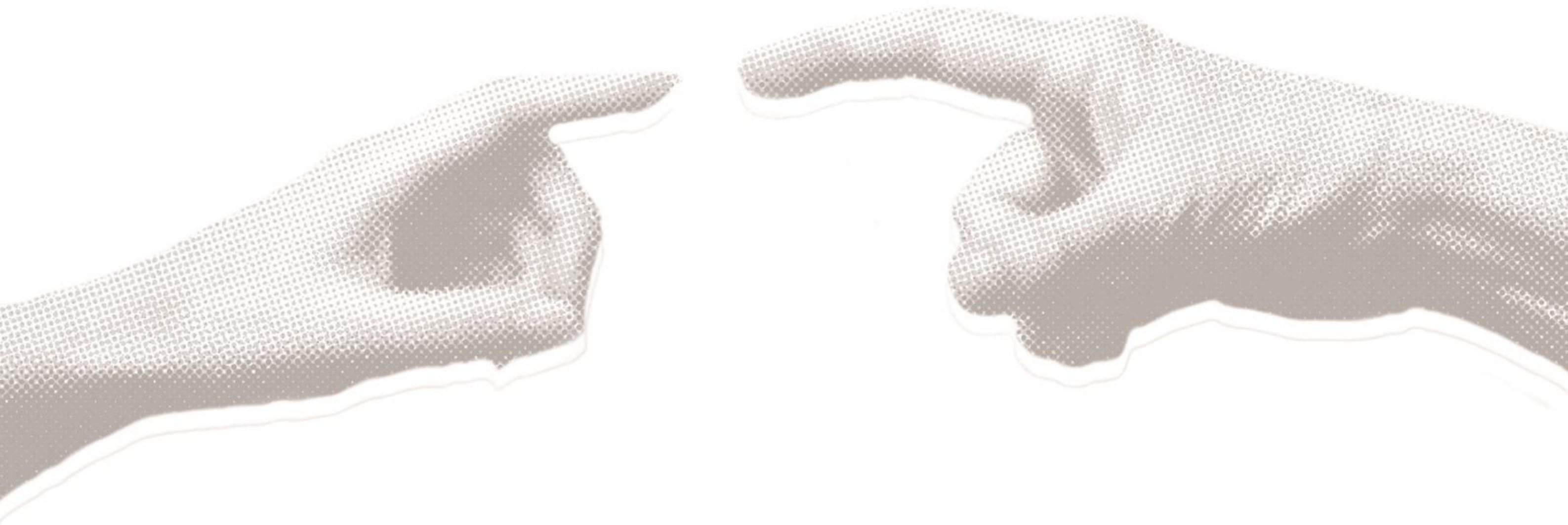
A potential limitation of Experiment 2 is that response data of the observed pictures in the encoding phase, such as eye fixations, were not recorded, because that would change the experimental procedure too much. Therefore, we could not check whether participants attentively looked at the pictures in the observation only condition. However, participants were explicitly instructed to visually attend to all stimuli, and they had to attend to stimuli to be able to determine whether or not they had to point at pictures during encoding (e.g., point to the artificial pictures and only look at the natural pictures). Given that the accuracy during encoding of pointing (i.e., pointing at the items that should be pointed at) was high (young, M = 99.41%, SD = .01; old, M = 98.81%, SD = .02) and the number of false responses (pointing at pictures that should only be observed) was low (young, M = 0.33%, SD = 1.51; Old, M = 0.52%, SD = 0.92), we can assume that participants paid close attention to all pictures during encoding.

Another potential limitation for the present findings might be that pointing itself did not enhance source memory performance, but that the positioning of the hands near the stimuli during encoding was sufficient. Evidence shows that performance on all kinds of cognitive control tasks improves if stimuli are perceived near the hands, for example tasks targeting spatial attention (Reed, Grubb, & Steele, 2006), visual working memory (Cosman & Vecera. 2010; Tseng & Bridgeman, 2011), and executive functioning (Weidler & Abrams, 2014). These findings can be explained by the selection-for-action hypothesis (Allport, 1989), which proposes that action intentions toward objects increase attention for these objects compared with objects that people do not intend to act upon. It would be interesting for future research to conduct a series of experiments to find out whether hand position alone can enhance spatial source memory, as to the best of our knowledge, this has not been investigated yet. In addition, another interesting direction for future research would be to investigate whether mere motor planning, without the execution of the movement itself (e.g., through mental imagery), might be sufficient to add a motor code to the memory that can enhance subsequent memory performance, and whether the specifics of the motor plan matter (e.g., object-directed vs. another direction of movement). This would provide further insight into the mechanisms underlying the effects found in the present study.

Although further research is needed, our results suggest that pointing gestures at an object during encoding can provide a cue that helps to focus attention in a body-based (egocentric) manner, and consequently might assist in retrieving the object's locations at a later stage. This means that in daily life, pointing at an object might be an effective strategy for remembering its location at a later point of time, which might be especially helpful for older people.

Chapter 5

Effects of semantic congruency and pointing gestures on item and source memory in children and young adults



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Abstract

This study investigated whether source memory is superior for picture locations that are congruent with dominant past perceptual experiences (e.g., a cloud presented at the upper side of the screen), or incongruent (e.g., grass presented at the upper side of the screen), and whether pointing gestures toward picture locations can enhance source memory performance. Children (Experiment 1) and young adults (Experiment 2) encoded a sequence of pictures by either pointing to the pictures' location or only observing them. Results showed that source memory accuracy was superior for congruent compared with incongruent picture-location associations in both experiments. Pointing resulted in lower accuracy of item memory on the incongruent trials than observation only in children. In young adults, pointing did not affect accuracy but did result in faster responses overall. In conclusion, the congruency effect for source memory of picture-location associations in both children and young adults points at an early and robust influence of dominant experiences with object locations on memory.

Introduction

The experience that you do know *that* you saw an object recently (e.g., your set of keys) but not *where* you saw it is a familiar one for most people. Remembering *that* you saw your keys is called "item memory", that is memory for facts in isolation. Remembering *where* you last saw your keys is called "source memory", that is memory for contextual features linked to a particular item (Van Petten, Senkfor, & Newberg, 2000).

Research has shown that children perform less well on source and item memory tasks than young adults, but that this age-related difference is larger for source memory (Cycowicz, Friedman, Snodgrass, & Duff, 2001; Sprondel, Kipp, & Mecklinger, 2011). In addition, developmental studies have shown a larger improvement of source memory performance than item memory performance from childhood (7-8 years) to adolescence (13-14 years; Sprondel et al., 2011) and from childhood (7-9 years) to young adulthood (Cycowicz et al., 2001). These findings are explained by evidence showing that the development of source memory is associated with that of the frontal lobes (e.g., Dobbins, Foley, Schacter, & Wagner, 2002; Trott, Friedman, Ritter, Fabiani, & Snodgrass, 1999), a brain area that does not fully mature until young adulthood (Sowell, Thompson, Holmes, Jernigan, & Toga, 1999). Source memory tasks come in different forms, requesting different types of item-source associations, for example, object-color (e.g., Cycowicz & Friedman, 2003), object-background (e.g., Glisky, Rubin, & Davidson, 2001), spoken words-voice (e.g., Senkfor & Van Petten, 1998), and object-location associations (e.g., Cansino, Maquet, Dolan, & Rugg, 2002).

Based on the theory of grounded cognition, that states that previous perceptual and bodily experiences shape our cognition (for a review, see Barsalou, 2008), we propose that some item-source pairs might be easier to remember than others, because they are congruent with pre-existing knowledge and previous experiences. According to this theory, cognition (including memory) is grounded in perceptual and motoric simulation. For example, imagining an object (e.g., a kite) seems to elicit similar brain activation patterns as actually seeing that object (Ganis, Thompson, & Kosslyn, 2004), and similarly, imagining an action or seeing someone else perform that action seems to elicit similar brain activation patterns as actually performing that action (Rizzolatti & Craighero, 2004). Simulations are multimodal; apart from the visual modality, they contain relevant motor and mental states that were part of the original experience (Dijkstra & Zwaan, 2015). For example, thinking of or seeing a picture of a flying kite might be associated with the motor response of "looking up".

Because such mental simulations are activated automatically (Barsalou, 2008), perception and memory may be influenced by pre-existing knowledge and earlier experiences without extra effort or even conscious awareness. For instance, Pecher, Van Dantzig, Boot, Zanolie, and Huber (2010) gave participants a semantic decision task in which they had to decide whether an item (a word) represented an object belonging in the sea or in the sky. The items were presented either at the top or bottom of a computer screen. It was found that responses were faster for items that were presented on a congruent location (e.g., the word "whale" located at the bottom of the screen) than an incongruent location (e.g., the word "eagle" at the bottom of the screen). The authors suggest that this congruency effect occurs because humans mentally simulate an image of the word meaning and its location, so that their attention is automatically shifted toward the congruent location. In addition, such an attentional bias was also found for more abstract concepts such as "power" (which is associated with "looking up"; Zanolie et al., 2012). However, these studies showed a spatial congruency effect in tasks that required an immediate response (e.g., a semantic decision task, or target identification task). To the best of our knowledge, it has not yet been investigated whether this spatial congruency also affects item and source memory performance, and how previous experiences affect item and source memory in children and young adults.

Applied to item-source memory then, we propose that congruent pairs, such as a picture-location pair like a picture of a flying kite presented at the upper half of a computer screen, should be easier to remember than incongruent pairs, such as the picture of the flying kite located at the lower half of a computer screen. Therefore, the first question addressed in the present study is whether item memory and spatial source memory performance would be superior for pictures in a congruent (e.g., a picture of a cloud presented at the upper halve of the screen) compared with an incongruent location in children (Experiment 1) and young adults (Experiment 2).

In addition it was investigated whether item memory and spatial source memory performance in children (Experiment 1) and young adults (Experiment 2) could be improved by enriching the visual perception of pictures at different locations with an action, specifically a pointing gesture, during encoding. Pointing gestures are among the most robust gestures in humans, and children already use pointing gestures to index objects and locations before they are able to speak (Iverson & Goldin-Meadow, 2005). There is some evidence that suggests that pointing at stimuli can enhance memory. For example, Chum, Bekkering, Dodd, and Pratt (2007) showed that manually pointing at simple stimuli (circles or squares) at different locations, led to better visuospatial working memory for these locations than visual observation only. In addition, Ouwehand, Van Gog, and Paas (2015) showed that pointing at picture locations led to superior source memory for picture-location associations compared with observation only. A possible explanation for the positive effect of pointing in these studies can be found in the selection-for-action hypothesis (Allport, 1989), that states that objects that require an action or are intended to be acted upon, receive more attention. We suggest that by this attentional bias, these objects get encoded and processed better and consequently, remembered better, than those that do not require action. Although both source and item memory are still developing in children, the changes in source memory are more pronounced and take place well into young adulthood (Cycowicz et al., 2001; Ruffman et al., 2001). Therefore, pointing gestures might have distinct effects on source and item memory, as well as on children and young adults.

The present study

Two experiments were conducted to investigate the potential effect of semantic congruency and pointing gestures toward picture locations on spatial source memory performance (in terms of accuracy as well as reaction times) for congruent and incongruent picture-location pairs in children (Experiment 1) and young adults (Experiment 2). Because Barsalou (2008) stated that “locating objects along the vertical axis of the body is easiest because of the body’s perceived asymmetry with respect to the ground” and “locating objects along the left-right axis is most difficult because environmental and bodily cues are lacking” (p. 625), the present study used only a “top-bottom” distinction for the manipulation of spatial locations of the pictures. Our first hypothesis is that, in line with a grounded cognition perspective (Barsalou, 2008), item and source memory in both children and young adults would be better for picture-location associations that are congruent with previous experiences compared with those that are incongruent.

Our second hypothesis is that pointing gestures would enhance source memory for locations, resulting in higher source memory performance for picture-location associations that are pointed at than for those only observed (cf. Ouwehand et al., 2015, Chapter 4; Chum et al., 2007). Pointing at picture locations during encoding forces participants to act upon the pictures and their location. Moreover, the selection-for-action hypothesis suggests an attentional bias toward objects that require action. Pointing thus should facilitate source memory. From the selection-for-action hypothesis we might also infer that the content of pointed pictures might be better encoded, because they are acted upon. This would have an effect on item memory and this possible effect will be explored also in this study.

Experiment 2 was identical to Experiment 1, but conducted with young adults. We chose for a replication study with young adults, to find out whether or not any effects found in children (i.e., a population with suboptimal source memory performance) would also apply to young adults, who have more developed source memory (Cycowicz et al., 2001).

General method

Design

Both experiments had a 2 (Encoding Condition: pointing vs. observation only) x 2 (Congruency: congruent vs. incongruent) mixed design with encoding condition as a between-subjects factor and congruence as within-subjects factor. Half of the participants were instructed to point with their index finger at the pictures and the other half just had to look at these pictures.

Materials

The experimental task was programmed in E-prime 2.0 and presented on a 17-inch ELO touchscreen with a 1024 x 768 resolution, tilted backwards at an angle of 30°. Stimuli were a set of photos showing natural scenes and or objects that are associated with looking up (e.g., clouds) or looking down (e.g., grass). In total, 74 pictures were used, 14 for the practice phase and 60 for the experimental phase. Accuracy and reaction times of the pointing responses were recorded by the touchscreen.

Procedure

Participants were tested in individual sessions of approximately 10 min. The task started with a short practice phase in which participants were familiarized with the task.

Encoding phase. The encoding phase consisted of 40 trials, each trial presenting a picture at the upper or lower half of the screen (see Figure 1). The pictures were equally divided over four categories; congruent top (picture associated with looking up is presented in the upper part of the screen), incongruent top (picture associated with looking down is presented in the upper part of the screen), congruent bottom (picture associated with looking down is presented in the lower part of the screen), incongruent bottom (picture associated with looking up is presented in the lower part of the screen). Half of the pictures depicted objects or sceneries associated with looking up (e.g., a cloud) and the other half with looking down (e.g., grass).

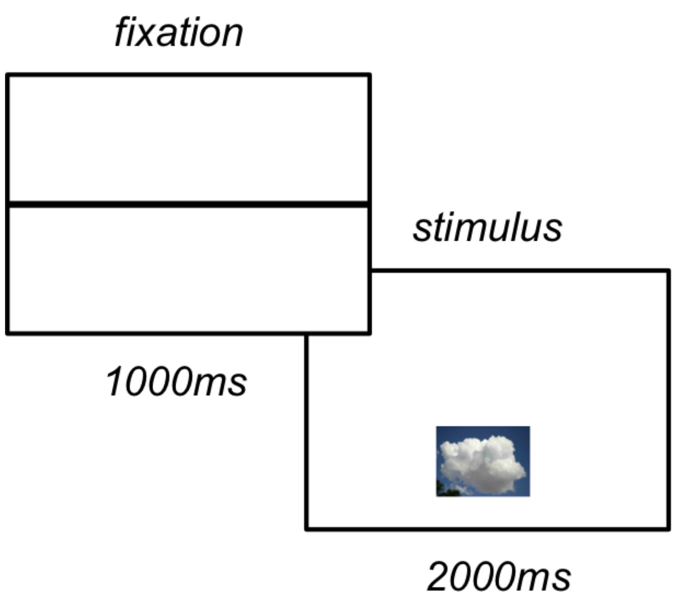


Figure 1. Procedure of a trial in the study (encoding) phase of the task.

Each trial started with the presentation of a black horizontal midline dividing the screen in the upper and lower half with a white background color in two equal halves for 1000 ms. Participants were instructed to fixate at the center of the midline. Next, a picture was presented above or under the midline for 2000 ms. In Figure 1 the procedure of an encoding trial is depicted.

Test phase. In the test phase, 60 pictures (the 40 pictures from the study phase and 20 new pictures) were shown. Each trial started with a fixation cross (1000 ms), presented at the center of the screen, followed by a picture presented at the center of the screen (1000 ms). Then, participants had to make an old/new judgment of whether or not they had seen the picture in the encoding phase by pressing on the word “YES” or “NO” at the touchscreen. When participants judged the picture to be new, they progressed to a new trial, but when they judged it to be old, they were asked to judge at which of the two locations they had seen the picture in the encoding phase, by pressing one of the following words at the touchscreen, “TOP” or “BOTTOM”, presented in boxes in corresponding locations. In Figure 2, the trial procedure of the retrieval phase is depicted.

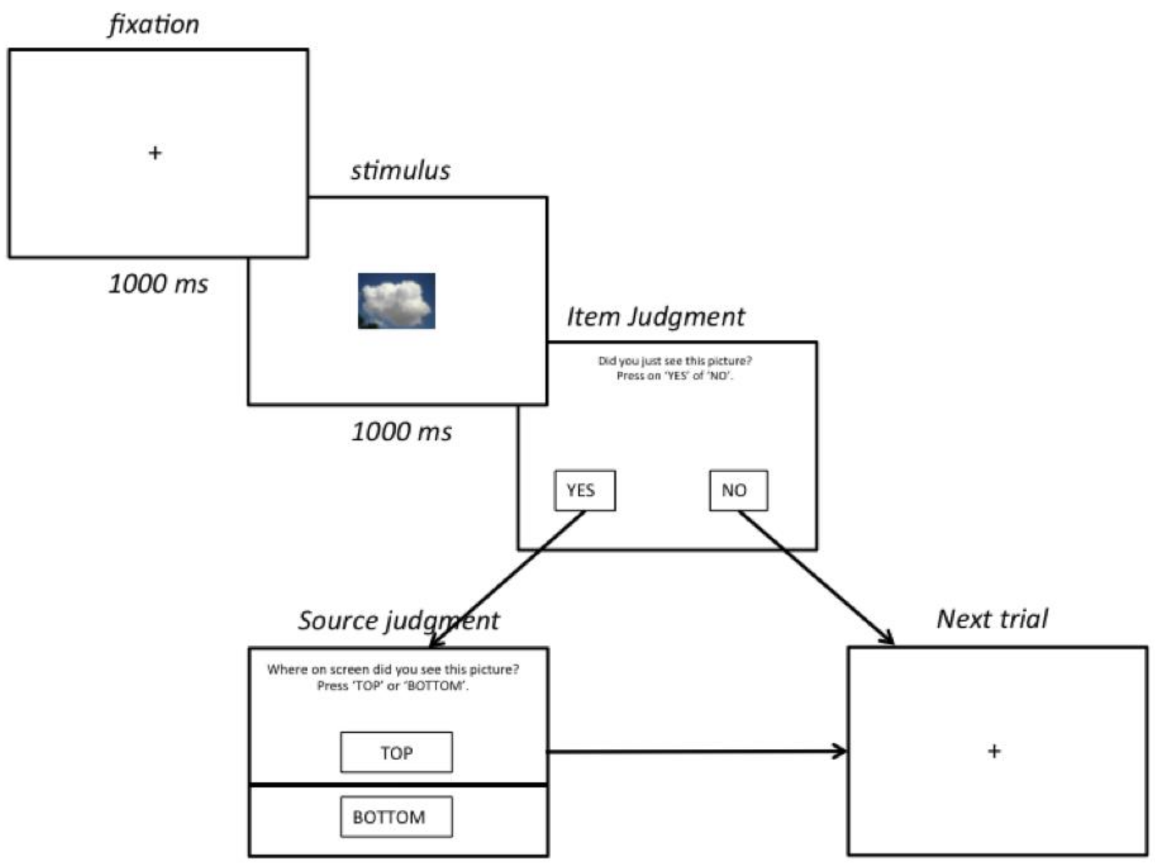


Figure 2. Procedure of a trial in the test (retrieval) phase of the task.

Data Analysis

For both Experiments 1 and 2, percentage scores were calculated per experimental group (pointing and observation only) for *item memory* accuracy for pictures presented at a congruent (i.e., total correct item congruent/(20/100)) or incongruent location, (i.e., total correct item incongruent(20/100)). This was also done for *source memory* accuracy for congruent (i.e., total correct source congruent/(total correct item congruent/100)) and incongruent (i.e., total correct source congruent/(total correct item congruent/100)) picture-location pairs.

Experiment 1

Participants

Participants were 123 children (68 boys, M_{age} = 8.7 years, *SD* = 0.98 years, age range 7–10 years), who visited a Dutch Science Museum. Parents had to give written consent for their child(ren)'s participation and all children participated voluntarily. The experiment took place in a separate room in the museum.

Results

Means and standard deviations of the item and source memory performance and reaction times can be found in Table 1.

The analysis on item memory accuracy yielded a main effect of encoding condition, $F(1, 121) = 4.74$, $MSE = 0.04$, $p = .031$, $\eta_p^2 = .04$, but no effect of congruency, $F(1, 121) = 0.94$, $MSE = 0.01$, $p = .333$, $\eta_p^2 < .01$. The main effect of encoding condition was qualified by a significant interaction effect, $F(1, 121) = 4.39$, $MSE = 0.01$, $p = .038$, $\eta_p^2 = .04$. To further inspect the interaction effect, paired samples t-tests were conducted comparing accuracy between congruent and incongruent trials for each encoding condition, and independent samples t-tests comparing accuracy between encoding conditions for congruent and incongruent trials separately. Results of the paired samples t-tests showed no difference in item accuracy between congruent and incongruent trials in the pointing group, $t(65) = 2.22$, $p = .030$ (after Bonferroni adjustment of the significance level .05/2 = .025), or in the observation only group, $t(58) = -.78$, $p = .438$. Results of the independent samples t-tests showed no difference between encoding conditions for the congruent trials, $t(121) = 1.02$, $p = .312$, but a significant difference for the incongruent trials, $t(121) = 2.73$, $p = .007$ (see Figure 3). Analysis of reaction times of the item memory responses, showed no effect of encoding condition, $F(1, 121) = 0.55$, $MSE = 564197.31$, $p = .458$, $\eta_p^2 < .01$, congruency, $F(1, 121) = 2.26$, $MSE = 97520.15$, $p = .135$, $\eta_p^2 = .02$, nor an interaction effect, $F(1, 121) = 1.97$, $MSE = 97520.15$, $p = .163$, $\eta_p^2 = .02$.

The analysis on source memory accuracy showed no effect of encoding condition $F(1, 121) = 0.38$, $MSE = 0.04$, $p = .540$, $\eta_p^2 < .01$, a main effect of congruency, $F(1, 121) = 31.41$, *MSE* = 0.29, $p < .001$, $\eta_p^2 = .21$, but no interaction, $F(1, 121) = 0.43$, *MSE* = 0.29, $p = .516$, $\eta_p^2 < .01$. The congruency effect reflects superior source memory for congruent compared with incongruent picture-location associations. Analysis of reaction times of the source memory responses showed no effect of encoding condition, $F(1, 121) = 0.83$, *MSE* = 914655.62, $p = .365$, $\eta_p^2 < .01$, or congruency, $F(1, 121) = 0.13$, *MSE* = 263190.11, $p = .722$, $\eta_p^2 < .01$. However, a significant interaction effect was found, $F(1, 121) = 4.11$, *MSE* = 263190.11, $p = .045$, $\eta_p^2 = .03$. To further inspect this interaction effect, paired samples t-tests were conducted comparing the RT's between congruent and incongruent trials for each encoding condition, and independent samples t-tests comparing RT's between encoding conditions for congruent and incongruent trials separately. Results of the paired samples t-tests did not show a congruency effect in the pointing, $t(65) = 1.41$, $p = .164$, or the observation only group, $t(58) = -1.45$, $p = .154$. Results of the independent samples t-tests did not show a difference between the pointing and the observation only group on congruent trials, $t(121) = -.14$, $p = .887$, and although reaction times seemed to be faster in the pointing than in the observation condition on incongruent trials, this was not statistically significant, $t(121) = 1.92$, $p = .059$.

Table 1.
Means (and SD) of the Item and Source Memory Performance (Accuracy and RT's) for Spatially Congruent and Incongruent Picture-Locations Pairs in Experiment 1

		Pointing (*n* = 65)				Observation Only (*n* = 58)			
		Item		Source		Item		Source	
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Children	Acc C (*%)*	65.23	14.35	69.43	21.08	68.02	16.11	72.36	16.47
(*N* = 123)	Acc I (*%)*	61.00	18.01	58.68	17.22	69.57	16.68	58.78	17.40
	Mean (%)	63.12	14.35	64.05	14.12	68.79	14.55	65.57	13.11
	RT C (ms)	1211	617	1128	814	1196	410	1107	877
	RT I (ms)	1328	755	1019	442	1200	410	1263	876
	Mean (%)	1270	651	1074	575	1198	352	1184	774

Note. C = congruent; I = incongruent.

Discussion

In line with our expectations, we found a congruency effect for source memory. Participants were more accurate in recalling the congruent picture locations than the incongruent picture locations. In contrast to our expectations, however, pointing did not have a beneficial effect on source memory accuracy.

On the item memory test, we even found that the children in the pointing condition were less accurate on the incongruent trials than the children in the observation only condition. Possibly, this effect might have occurred because pointing toward an incongruent compared with a congruent location required additional cognitive control to deal with the interference. Therefore, fewer attentional resources might have been available for the encoding of the incongruent compared with the congruent stimuli, resulting in lower item memory accuracy in the pointing condition than the observation only condition. Evidence shows that cognitive control processes including interference control are still developing in children (e.g., Bunge, Dudukovic, Thomason, Vaidya, & Gabrieli, 2002).

We stipulate that young adults, who have a better developed cognitive control system, would have less trouble dealing with the interference and pointing toward incongruent picture locations than children. Pointing may therefore not affect young adults' item memory negatively. To explore this assumption and to investigate the effect of congruency and encoding condition in the same task in young adults, Experiment 2 was conducted.

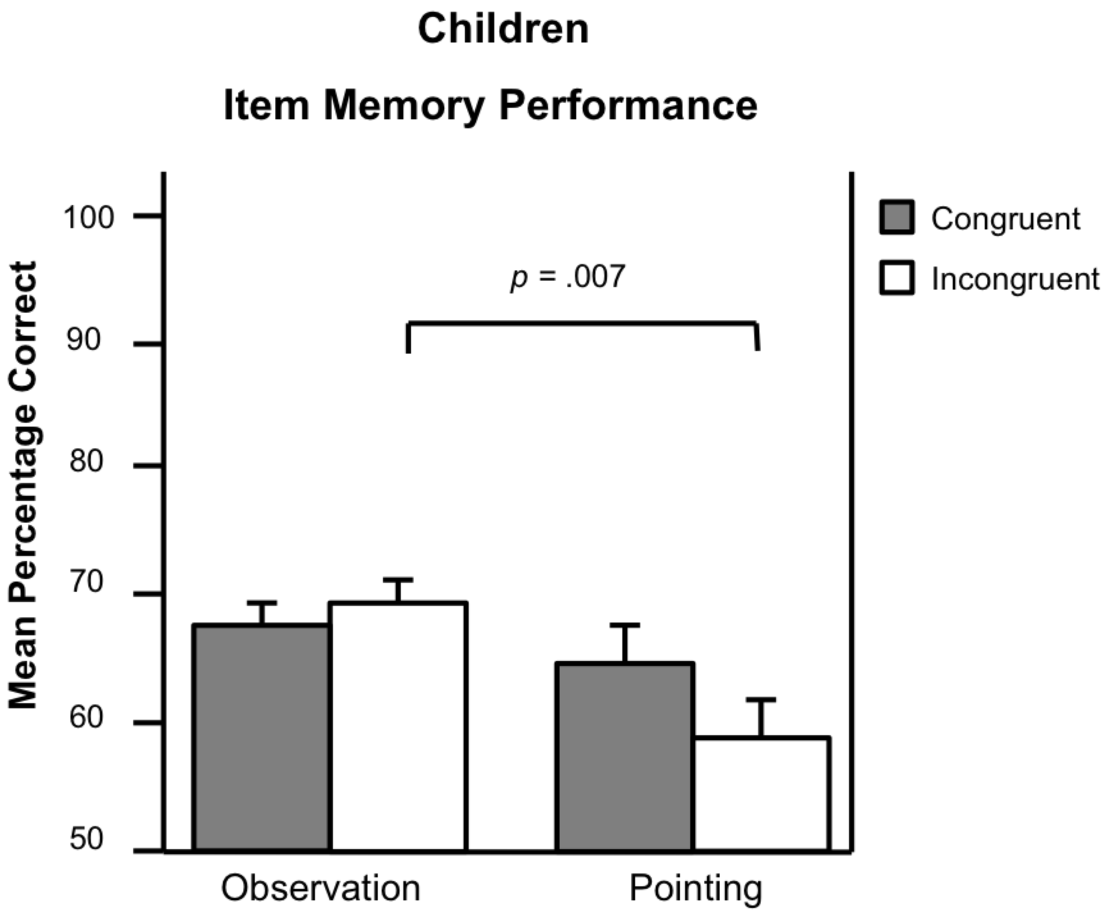


Figure 3. Performance expressed in percentage correct on the item memory task. Children in the Observation only condition outperformed those in the Pointing condition on the incongruent trials but not the congruent trials.

Experiment 2

Participants

Participants were 65 young adults (58 women, M_{age} = 20.0 years, *SD* = 2.9, age range 17–34 years), enrolled at a Dutch university. They participated for course credit or voluntarily.

Results

Means and standard deviations of the item and source memory performance and reaction times can be found in Table 2.

Table 2.
Means (and SD) of the Item and Source Memory Performance (Accuracy and RT's) for Spatially Congruent and Incongruent Picture-Location Pairs in Experiment 2

		Pointing (*n* = 32)				Observation Only (*n* = 33)			
		Item		Source		Item		Source	
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Adults	Acc C (*%)*	77.50	15.91	84.09	13.04	83.03	14.08	89.64	9.87
(*N* = 65)	Acc I (*%)*	75.31	17.73	75.78	17.24	82.12	13.11	80.48	15.70
	Mean (%)	76.41	15.73	79.94	12.24	82.58	12.46	85.06	11.20
	RT C (ms)	577	167	482	187	699	324	541	246
	RT I (ms)	609	205	490	191	759	293	594	286
	Mean (%)	593	175	486	172	729	278	567	252

Note. C = congruent; I = incongruent.

The analysis on item memory accuracy showed no effect of encoding condition, *F*(1, 63) = 3.08, *MSE* = 0.04, *p* = .084, η_p^2 = .05, congruency, *F*(1, 63) = 1.18, *MSE* = 0.01, *p* = .282, η_p^2= .02, nor an interaction, *F*(1, 63) = .20, *MSE* = .01, *p* = .655, η_p^2 < .01. Analysis on reaction times of the item memory responses, showed an effect of encoding condition, *F*(1, 63) = 5.52, *MSE* = 108982.66, *p* = .022, η_p^2 = .08, but there was no effect of congruency, *F*(1, 63) = 3.05, *MSE* = 22400.37, *p* = .086, η_p^2 = .05, nor an interaction, *F*(1, 63) = 0.29, *MSE* = 22400.37, *p* = .592, η_p^2 < .01. The effect of encoding condition reflected faster responses in the pointing than in the observation only condition (see Table 2).

The analysis on source memory accuracy yielded no effect of encoding condition *F*(1, 63) = 3.05, *MSE* = 0.03, *p* = .086, η_p^2 = .05, a main effect of congruency, *F*(1, 63) = 19.33, *MSE* = 0.01, *p* < .001, η_p^2 = .24, but no interaction effect, *F*(1, 63) = 0.04, *MSE* = 0.01, *p* = .843, η_p^2 < .01. The main effect of congruency reflects superior source memory for congruent compared with incongruent picture-location (see Table 2). Analysis of the reaction times of the source memory responses showed no effect of encoding condition, $F(1, 63) = 2.30$, $MSE = 93585.06$, $p = .134$, $\eta_p^2 = .04$, congruency, $F(1, 63) = 2.13$, $MSE = 14009.95$, $p = .150$, $\eta_p^2 = .03$, nor an interaction, $F(1, 63) = 1.10$, $MSE = 14009.95$, $p = .299$, $\eta_p^2 = .02$.

Discussion

As in Experiment 1, we did find a congruency effect for source memory. This again supports our hypothesis that picture locations congruent with past experiences are better remembered than those that are incongruent. In contrast to our hypothesis regarding pointing, however, we found no positive effects of pointing on item or source memory accuracy. With regard to reaction times on item memory, however, participants in the pointing condition were faster than those in the observation only condition. Note that no positive effect of pointing on item memory reaction time was found for children. We will speculate on a possible explanation in the general discussion.

General discussion

In line with our expectations, we found a clear congruency effect for both the children and young adults on source memory accuracy: participants remembered more locations of pictures presented at congruent locations than incongruent locations. This finding is in accordance with the theory of grounded cognition that states that cognition is shaped by previous perceptual and bodily experiences with stimuli (Barsalou, 2008). If the appearance of a stimulus is incongruent with existing knowledge of that stimulus, then the encoding –and hence the recollection- of that stimulus seems to be negatively affected. This finding is also consistent with previous studies showing that spatial representations of words (Pecher et al., 2010) and abstract concepts (e.g., "power"; Zanolie et al., 2012) are shaped by pre-existing knowledge and grounded in previous experiences. However, these studies showed a spatial congruency effect in tasks that required an immediate response (e.g., a categorization task, or target detection task). The present study showed that pre-existing knowledge also influenced performance on spatial source memory for picture locations that required a response after a short retention period.

In contrast to earlier research showing that pointing can have a positive effect on memory compared with visual observation only, both on visuospatial working memory (Chum et al., 2007) and spatial source memory (Ouwehand et al., 2015), the present study did not find beneficial effects of pointing. In fact, for item memory in the present study, children in the pointing condition were even less accurate than those in the observation only condition, when the pictures were presented in incongruent locations. As mentioned in the discussion of Experiment 1, a possible explanation for this negative effect of pointing might be that the act of pointing at a picture positioned at an incongruent location induced interference. Children's cognitive control system dealing with this interference is still in development and does not function optimally yet (Bunge et al., 2002). As a result, fewer cognitive resources might have been available for the encoding of the incongruent compared with the congruent stimuli.

In line with this claim, in young adults there was no negative effect of pointing on item memory accuracy, probably because their control over interference is more optimal. In fact, young adults in the pointing condition also responded faster on the item memory test overall than those in the observation only condition. This suggests that young adults can efficiently deal with the interference of pointing toward an incongruent location during encoding, and even benefit from pointing in terms of speed of recognition. So, why would pointing lead to faster reaction times? The act of pointing in addition to observing the pictures might have created a more elaborate memory trace, which increased the experience of familiarity during the retrieval phase. Item memory is often thought to involve two processes, familiarity and recollection. Familiarity reflects a fast quantitative (experiencing more or less familiarity) memory signal (Rugg & Yonelinas, 2003), which makes an individual experience of something feel familiar without recalling any qualitative information (the source of the memory; Diana, Yonelinas, & Ranganath, 2007). Recollection is a slower recognition process where an individual can retrieve the item and its specific details explicitly. It is possible that an effect of pointing on item recognition reaction times in children was absent because they are not able yet to make use of the familiarity mechanism in recognition, but instead, they rely on the slower recollection mechanism (Sprondel et al., 2011). The finding that the reaction times of the children are roughly two times higher than those of the young adults do support the speculation that the children did rely on the slower recollection process for the source and item memory tests.

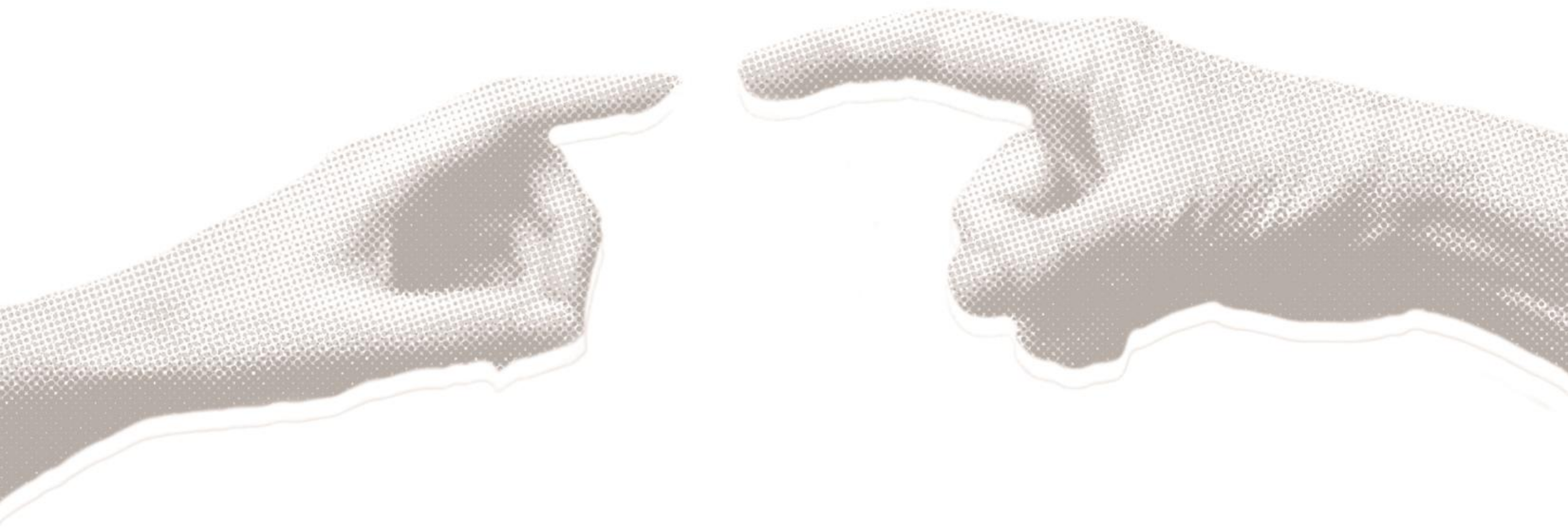
In terms of potential explanations for the absence of a positive effect of pointing on source memory accuracy in both children and young adults, an important difference between the present study and previous studies that did find such an effect lies in the design. The previous studies that found a beneficial effect of pointing used an experimental design in which participants had to select a response (point and observe or observe only) within trials depending on the type of stimuli presented to them. For example, in the study by Chum et al. (2007), participants were presented with trials showing circles and squares at different locations at the screen and were instructed to point to one type of stimuli (e.g., the squares) and only observe the other (e.g., the circles). Interestingly, when Dodd and Shumborski (2009) used the paradigm from Chum et al., but requested participants to point at *or* only observe all stimuli within a trial, the effect reversed, in that memory for the observed figures was superior to memory of the pointed figures. The authors suggest that the positive effect of pointing may be dependent on the task demands during encoding; if the task requires a selection process for a subset of the stimuli, pointing facilitates further processing and memory for these items.

In the context of the selection-for-action hypothesis (Allport, 1989) this would mean that selection for action creates an attentional bias toward objects that require action, but that a difference in memory performance can only be detected when pointing versus observation is manipulated within subjects. This would also explain the positive effects of pointing over observation only in the study by Ouwehand et al., (2015, Chapter 4) that used a within-subjects design in which participants had to select one of two responses randomly in the encoding phase (i.e., point to one type of stimuli and name the location of the other type of stimuli). The present study did not require such a selection process, because a between-subjects design was used. Although Dodd and Shumborsky investigated a different type of memory (visuospatial working memory) than the present study (spatial source memory), and we did not find a reversed effect, we do consider this “selectivity account” a likely explanation for the present results. Future research should investigate whether or not the need for selection moderates the effect of pointing on spatial source memory, by comparing findings in a within-subjects design in which participants point and observe, to a between-subjects design in which participants either point to or only observe picture locations during encoding.

A potential limitation of the present study is that the children and young adults had a different experimental environment; the children were tested in a separate room in a science museum whereas the young adults were tested at the university in a laboratory designed for experimental research. It is possible that the children experienced more distraction than the young adults, because the room in the museum was less quiet than the lab spaces at the university. Nevertheless, the fact that we found a congruency effect in Experiment 1, and replicated it in Experiment 2, makes it seem less likely that the experimental environment had a large effect on the results. To conclude, the congruency effect for source memory of picture-locations associations suggests that dominant (location) experiences with objects or scenes have a robust influence on spatial source memory, even if these object or scenes are presented as pictures on a computer screen. This suggests that our memory for counterintuitive contextual features is more sensitive to errors than contextual features that are in alignment with previous experiences, at least, for objects and scenes that are associated with looking up or down.

Chapter 6

Effects of pointing gestures on visuospatial working memory in young and older adults



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Abstract

This study investigated whether visuospatial working memory performance of young and older adults improved from a multimodal compared with a unimodal encoding strategy. In Experiment 1, participants were presented with a sequence of simple figures at different locations, consisting of an array of squares and an array of circles. They were instructed to point at (multimodal encoding strategy) one type of figure and only observe the other (unimodal encoding strategy). After each trial an immediate location recognition test of one of the two arrays followed. In Experiment 2 the same task was used, but a cue was provided about which of the two arrays would be tested, either before or after the encoding phase. Results showed that a multimodal compared with a unimodal encoding strategy improved visuospatial working memory performance in both young and older adults (Experiment 1) and that adding visual cues to the multimodal but not to the unimodal encoding strategy improved older adults' performance (Experiment 2). In both age groups, cueing before encoding led to higher performance in the multimodal than in the unimodal condition when the *first* array of the figure sequence was tested. However, cueing after encoding led to higher performance in the multimodal than in the unimodal condition when the *second* array was tested. These results suggest that predictive cueing together with pointing can have beneficial effects on visuospatial working memory, which is especially important for older adults.

Introduction

Healthy aging has been associated with declines in working memory functioning (e.g., Salthouse & Babcock, 1991), cognitive speed (Salthouse, 1996; 2000), and interference control (e.g., Houx, Jolles, & Vreeling, 1993; Stolzfus, Hasher, Zacks, Ulivi, & Goldstein, 1993). Consequently, it is important for older adults' functioning to find strategies to compensate for these age-related cognitive declines. With regard to improving memory, one such strategy might be the adoption of a multimodal (visual-motoric) instead of a unimodal (visual only) encoding strategy that has been found to have a positive effect on young adults' visuospatial working memory performance (Chum, Bekkering, Dodd, & Pratt, 2007). Chum et al. (2007) found that visuospatial working memory for figure locations that were manually pointed at during encoding was better than that for figure locations that were only visually observed. Participants were presented with a sequence of simple figures consisting of an array of squares and an array of circles, varying from three to five figures per array. The figures in each array were presented sequentially at different locations on the screen (encoding phase) and disappeared after a fixed presentation time; order of presentation of the two arrays was counterbalanced between trials. Participants were instructed to point at one type of figure (e.g., the squares; which type was also counterbalanced between participants). Immediately after encoding a trial, a test phase followed in which a configuration of either squares or circles was shown and participants had to judge whether or not the locations of the figures corresponded to the ones presented in the preceding sequence. Therefore the time lag between encoding and test phase varied depending on the order of array presentation during encoding. It was found that a multimodal (visual-motoric) encoding strategy led to better visuospatial working memory performance than a unimodal (visual only) encoding strategy, and participants performed better on test trials regarding the second array of figures than the array presented first. Moreover, Chum et al. found an interaction between encoding strategy and array size. Specifically, the interaction effect showed that the beneficial effect of a multimodal encoding strategy declined with increasing array size and even disappeared for the longest arrays (five circles and five squares).

One of the explanations for the facilitating effect of pointing on visuospatial working memory provided by Chum et al. (2007) was based on the selection-for-action hypothesis (Allport, 1989). This hypothesis holds that stimuli that we intend to act upon, receive more attention than stimuli that we do not intend to act upon. Hence, stimuli that require an action would be processed and encoded better. Furthermore, more recent evidence suggests that this attentional bias is related to whether or not the stimuli are perceived near the hands. If stimuli are perceived near the hands, beneficial effects on performance are found on all kinds of tasks involving cognitive control processes, such as spatial attention (Reed, Grubb, & Steele, 2006), visual working memory (Tseng & Bridgeman, 2011), and executive functioning (Weidler

& Abrams, 2014). Note that with pointing, the hand is brought in close proximity to the stimuli and the evidence described above showed that this enhances all kinds of cognitive tasks, including visual working memory. We therefore suggest that pointing can also enhance visuospatial working memory because an action is performed to a subset of stimuli (selection for action), and this causes an attentional bias toward the pointed stimuli over the stimuli that were only observed. We suggest that these findings are especially relevant for older adults because perceptual ability (Schneider & Pichora-Fuller, 2000) focused attention (Rösler, Mapstone, Hays-Wicklund, Gitelman, & Weintraub, 2005), working memory (Salthouse & Babcock, 1991), and executive functioning (Salthouse, Atkinson, Berish, & Diane, 2003) decline with aging.

The finding that the positive effect of pointing decreased and eventually disappeared with increasing array size is possibly related to the limited capacity of working memory. Working memory is known to have a capacity of around three to five items when processing information (Cowan, 2010). It would make sense that the effect of encoding strategy disappears if the amount of items to be remembered exceeds this limited working memory capacity (i.e., cognitive overload, see Paas, Tuovinen, Tabbers, & Van Gerven, 2003). As for the effect that participants performed better when the second array was tested compared with the first, Chum et al. (2007) called this 'a typical effect of temporal proximity', meaning that memory was improved because the time lag between encoding and test phase of the second array was shorter than that between the encoding and test phase of the first array. However, we propose that in trials in which the first array was tested, interference may not only have resulted from the time lag, but also from the presentation of new but irrelevant information during that time lag (i.e., the presentation of the second array).

Older adults have more problems with inhibiting irrelevant information than young adults (e.g., Houx et al., 1993; Stolzfus et al., 1993). However, this effect of age might depend on which type of inhibition is required. According to Hasher, Zacks, and May (1999) there are three inhibitory functions of working memory namely access, deletion (or suppression) and restraint. Relevant for the present study are the access and deletion function. The access function involves the inhibition of irrelevant stimuli from entering working memory, and the deletion function involves the selective deletion of irrelevant stimuli after they have entered working memory. A study by Cansino, Guzzon, Martinelli, Barollo, and Casco (2011) investigated these inhibitory functions in young and older adults with a visuospatial working memory task. In this task relevance was visually cued either before (targeting the access function) or after the encoding phase (targeting the deletion function). In the encoding phase participants saw a sequence of two circles consisting of Gabor elements (looking like dashed lines) in which one or more of the Gabor elements were missing. In the test phase participants were presented with a similar circle as in the encoding phase. Participants had to judge whether or not the test circle was missing the same Gabor element(s) as one of the circles presented in the preceding encoding phase. In the test conditions, participants received cues either presented before (access condition) or after (deletion condition) the encoding phase indicating which of the two circles was task relevant. In the control conditions, blank cues that did not provide information on task relevance were presented before or after the encoding phase. Comparing the test conditions with the control conditions, cueing relevance improved young adults' performance in both the access and the deletion condition. The performance of older adults on the other hand, only improved from cueing relevance *before* encoding, compared with the control condition. These results showed that older adults have no trouble filtering out or ignoring irrelevant information before it can access working memory, but have problems suppressing (i.e., deleting) irrelevant information after it has accessed working memory (Cansino et al., 2011).

We suggest that because in the study by Chum et al. (2007) task relevance became clear after stimulus presentation, this paradigm required only the deletion function. It would be interesting to investigate whether cueing can decrease the effect of order found in the study by Chum et al., that is, the difference in performance when the first compared with the second array is tested. If the length of the time lag between encoding and test phase is the sole factor, then the findings by Chum et al. that performance of the young adults was better when the second array was tested, should replicate regardless of whether cueing is done before or after encoding. However, if the time lag is not the only factor accounting for the effect of order, cueing relevance before encoding (targeting the access function) might be a promising way to enhance visuospatial working memory performance in the paradigm of Chum et al., in both young and older adults. Cueing after encoding (targeting the deletion condition) might have a positive effect on young adults' but not older adults' performance because the deletion function seems to malfunction in older adults (Cansino et al., 2011).

The present study

The present study consists of two experiments in which the paradigm of Chum et al. (2007) was used to find out whether a multimodal (visual-motoric) encoding strategy would lead to better visuospatial working memory performance than a unimodal (visual only) strategy not only for young, but also for older adults. Because Chum et al. found that the effect of encoding strategy declined in the larger arrays, we only used trials with three figures per array in this study. In addition, because aging is also related to reduced cognitive speed (Salthouse, 1996), we added trials with longer stimulus display times of 1500 ms per figure in Experiment 1, next to those with a display time of 1000 ms as used by Chum et al. In Experiment 2, the time versus stimulus interference explanations were tested by using the same paradigm, but now adding cues either before or after encoding about the array to be tested (cf. Cansino et al., 2011).

In Experiment 1, it was hypothesized that we would replicate the findings by Chum et al. (2007) for young adults and that this finding would extend to older adults. That is, performance accuracy would be higher and reaction times would be lower when young and older participants used a multimodal (visual observation and pointing) encoding strategy versus a unimodal (visual observation only) encoding strategy. We also expected to replicate the effect of order that performance would be better on the second than the first array.

In Experiment 2, we expected that the effect of order that Chum et al. (2007) found would stem from interference from the irrelevant array rather than purely from the temporal lag between encoding and test phase. Accordingly, we hypothesized that older adults' performance when tested on the first array, would be improved when a cue was provided before compared with after the encoding phase. For the young adults, who do not suffer from age-related declines in working memory functions, both types of cues would be expected to be effective, meaning that the effect of order was expected to disappear for young adults. It is an open question whether and how these cues would influence the effects of pointing during encoding that Chum et al. found. For instance, when cues would be sufficient for improving young adults' memory performance, they might no longer benefit from pointing or pointing and cueing may have additive effects. If our hypotheses regarding effects of cues on older adults would be supported, then we might expect them to still benefit from pointing on the trials where cues are presented after encoding. Regarding effects of cues presented before encoding, these may either make effects of pointing disappear, or may be additive to the effect of pointing.

General method

Materials and Procedure

The experimental task was programmed in E-prime 2.0 and presented on a 17 inch ELO touchscreen with a 1024 x 768 resolution, tilted backwards at an angle of 30°. The task took about 15 min to complete.

Participants were tested in individual sessions. The task started with a short training phase, in which participants were familiarized with the procedure of the trials. The encoding phase of each trial showed a figure sequence consisting of two arrays of three figures, that is, three white-filled circles and three white-filled squares. Half of the participants were instructed to point at the squares and only look at the circles and the other half was instructed to point at the circles and look at the squares. The presentation order (i.e., circles or squares first) was counterbalanced. The figures (i.e., circles or squares) in each array were presented sequentially in one of 20 possible positions on the screen and each location was only used once in the encoding phase of a single trial. The figures disappeared when they had been pointed at or after a maximum presentation of 1000 ms (as in Chum et al., 2007) or 1500 ms.

After the presentation of the two arrays in the encoding phase of a trial, a mask was presented for 150 ms. Next, the test phase followed, showing a configuration of three white-filled circles or squares. Participants had to judge whether or not the figures were positioned at the locations at which they were presented in the encoding phase, by pressing the word “correct” (as seen in the encoding phase) or “incorrect” on the touchscreen.

The total test consisted of 64 trials; in 32 trials the test-relevant array was encoded multimodally by pointing (visual-motoric), and in the other 32 trials the test-relevant array was encoded unimodally (visual only). In half of the 32 trials per encoding strategy, the first array was test-relevant, in the other half the second array. Of the 32 trials per encoding strategy, 16 trials presented each figure for 1000 ms and 16 for 1500 ms. Overall 50% of the test trials had to be answered with “correct” and 50% with “incorrect”. After this response, the next trial started. Figure 1 depicts the trial procedure of a trial with a figure display time of 1000 ms.

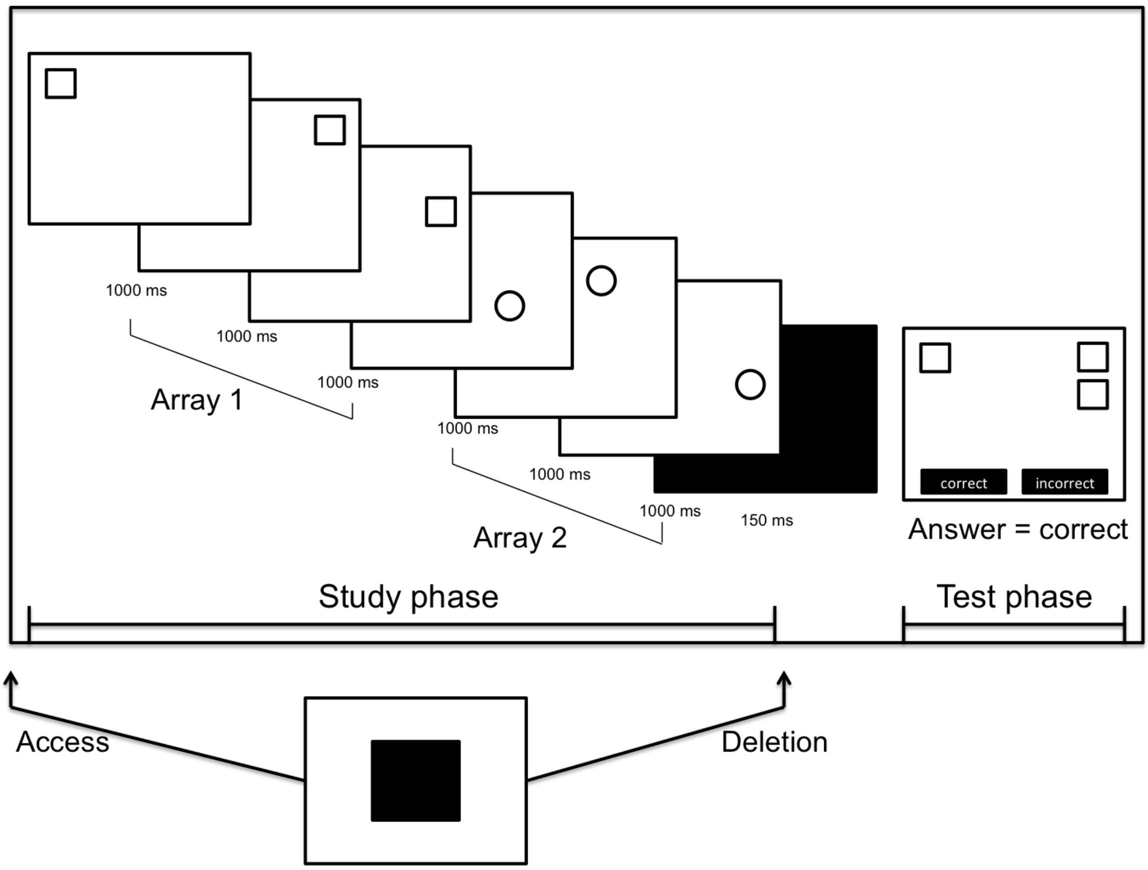


Figure 1. The upper part shows the trial procedure in Experiment 1 and the lower part shows the addition of cues in Experiment 2 presented either before (access function) or after (deletion function) the arrays were presented.

Data Analysis

For all analyses a significance level of .05 was used. Partial eta-squared (η_p^2) was calculated as a measure of effect size, with values of .01, .06, and .14, characterizing small, medium, and large effect sizes, respectively (Cohen, 1988).

For both the multimodal and unimodal encoding conditions, performance accuracy was determined by calculating the percentage of accurate judgments in the test phase (i.e., pressing “correct” when the configuration shown in the test phase was the same as during encoding or pressing “incorrect” when it was not). Participants who had an average performance below chance level (< 50%), or an average response time higher than 3000 ms were excluded from the analyses.

Experiment 1

Participants

Participants were 39 young adults (28 women, 11 men, M_{age} = 20.8 years, *SD* = 2.1, age range 18–26 years), who were all students enrolled at a Dutch university, and 38 older adults (23 women, 15 men; M_{age} = 67.1 years, *SD* = 4.3, age range 60–83 years), who had been recruited via advertisements in community centers. Advertisements called for healthy older adults (> 60 years of age) and during admission, participants were asked whether they had experienced a stroke (CVA or TIA), dementia, other cognitive problems, or any kind of brain damage or (mild) head trauma in the past. Participants who answered “yes” to one of these questions were not included in the sample. The young adults received course credit and the older adults received a small monetary reward (7.50 Euro) for their participation.

Materials and procedure

Prior to the experimental task described in the ‘general method’ section, a computerized operation span task (Unsworth, Heitz, Schrock, & Engle, 2005) was administered to obtain a general measure of cognitive functioning of both age groups. These types of working memory span tasks have been found to predict performance on a wide range of cognitive tasks (Engle, Tuholski, Laughlin, & Conway, 1999; Kane, Bleckley, Conway, & Engle, 2001) and share a large amount of variance among each other, indicating that they measure the same construct (Unsworth et al., 2005). Although a large body of evidence indicates that older adults show age-related cognitive decline compared with young adults (Cabeza & Dennis, 2013; Naveh-Benjamin, 2000; Old & Naveh-Benjamin, 2008; Spencer & Raz, 1995), this measure was taken to check whether this was also the case in the present sample.

The operation span task was programmed in E-prime 2.0. In this task participants were presented with arrays of letters intermixed with arithmetic problems they had to solve. Each trial started with a letter, followed by a problem, followed by a letter etc. In total 75 letters and 75 problems were presented in trials randomly varying in length from three to seven letter-problem pairs. One point was assigned for each letter that was recalled in the correct position in the array, which could result in a maximum score of 75.

Results

Operation span task

An ANOVA showed a significant difference in operation span score between young and older adults, $F(1, 75) = 26.72$, $MSE = 265.52$, $p < .001$, $\eta_p^2 = .26$, with, as expected, operation span in young adults being higher ($M = 41.41$, $SD = 18.54$) than in older adults ($M = 22.21$, $SD = 13.61$). The operation span score showed no significant correlation with mean performance accuracy on the experimental task of the young ($r = .255$, $p = .117$) or the older adults ($r = .237$, $p = .152$).

Experimental task

Accuracy and reaction time data were analyzed with a mixed 2 x 2 x 2 x 2 repeated measures ANOVA with within-subjects factors encoding strategy (multimodal vs. unimodal), order (first vs. second array was relevant), and presentation time (1000 ms vs. 1500 ms), and between-subjects factor age group (young vs. older adults). All means and standard deviations of the accuracy (%) and reaction times (ms) of Experiment 1 can be found in Table 1. For reasons of readability and manuscript length, only significant effects are discussed here; statistics for the analyses of Experiment 1 can be found in Table 2A, Table 2B (accuracy) and Table 3 (reaction times).

Table 1.
Means (and SD) of Accuracy (Acc) and Reaction Times (RT) in Experiment 1

			Young adults (*n* = 39)				Older Adults (*n* = 38)			
			1000 ms		1500 ms		1000 ms		1500 ms	
	Order		*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Pointing	1st	Acc (%)	76.59	13.96	78.74	14.83	63.39	16.48	69.97	16.89
	1st	RT (ms)	1606	433	1795	512	2049	813	2077	535
	2st	Acc (%)	91.59	8.07	91.15	13.63	83.18	13.40	80.84	13.45
	2st	RT (ms)	1515	458	1606	433	1681	404	1695	443
Observing	1st	Acc (%)	73.67	16.78	75.82	15.89	63.74	12.15	60.16	16.23
	1st	RT (ms)	1835	566	1935	683	2162	572	2185	597
	2st	Acc (%)	87.38	11.24	88.69	10.04	71.55	19.48	75.87	17.44
	2st	RT (ms)	1425	390	1525	501	1776	364	1841	455

Accuracy. The analysis of the performance accuracy data showed main effects of encoding strategy (multimodal > unimodal), order (2nd array test-relevant > 1st array test-relevant), and age group (young > older), but not of presentation time. However, the main effects of encoding strategy and order were qualified by a three-way interaction between time, encoding strategy, and order. No other interaction effects were found (see Table 2A; Omnibus test).

Because there was no factor for time in the original paradigm of Chum et al. (2007), this interaction was followed up on by analyzing performance on trials with 1000 ms display time per figure (as in the original paradigm) and 1500 ms display time per figure separately with 2 (encoding strategy) x 2 (order) ANOVAs with an adjusted alpha level of .05/2. In line with the findings by Chum et al. the first analysis (time = 1000 ms) yielded a main effect of encoding strategy and order. In addition, a significant interaction of encoding strategy and order was found, which was not present in the study by Chum et al. (see Table 2A; Follow up 1.1). The second analysis (time = 1500 ms) also yielded a main effect of encoding strategy, and order, but no interaction effect (see Table 2A; Follow up 1.2).

To further explore the origin of the interaction in the 1000 ms trials, two repeated measure ANOVAs were conducted with an adjusted alpha level of .05/2 on only the trials with 1000 ms figure display time; the first on trials in which the first array was tested (order = 1) and the second on trials in which the second array was tested (order = 2). The first analysis showed no effect of encoding strategy (see Table 2A; Follow up 2.1), but the second analysis did (see Table 2A; Follow up 2.2). Thus the interaction of time, encoding strategy, and order stemmed from an effect of encoding strategy that was specifically found in trials with 1000 ms figure display time, in which the second array was relevant. In these specific trials participants in both age groups performed significantly better in the multimodal encoding condition compared with the unimodal encoding condition (see Figure 2).

Table 2A.

Statistics of the Analyses and Follow-Up Analyses on Performance Accuracy in Experiment 1

Analysis	factor(s)	*df*	*MSE*	*F*	*p*	η_p^2
Omnibus Test	**A**	**75, 1**	**0.04**	**49.39**	**< .001**	**.44**
E x O x T x A	**E**	**75, 1**	**0.02**	**16.89**	**< .001**	**.18**
	E x A	75, 1		2.09	.153	.03
	O	**75, 1**	**0.02**	**188.43**	**< .001**	**.72**
	O x A	75, 1		< 0.01	.981	< .01
	T	75, 1	0.03	0.98	.326	.01
	T x A	75, 1		< 0.01	.984	< .01
	E x O	75, 1	0.02	0.93	.339	.01
	E x O x A	75, 1		0.58	.448	< .01
	E x T	75, 1	0.02	0.05	.827	< .01
	E x T x A	75, 1		0.43	.514	< .01
	O x T	75, 1	0.02	0.26	.609	< .01
	O x T x A	75, 1		0.08	.782	< .01
	E x O x T	**75, 1**	**0.02**	**5.14**	**.026**	**.06**
	E x O x T x A	75, 1		3.39	.070	.04
Follow up 1.1: T = 1000 ms	**A**	**75, 1**	**0.03**	**33.76**	**< .001**	**.31**
	E	**75, 1**	**0.02**	**9.10**	**< .001**	**.11**
	E x A	75, 1		0.46	.498	< .01
	O	**75, 1**	**0.02**	**93.41**	**< .001**	**.56**
	O x A	75, 1		0.04	.849	< .01
	E x O	**75, 1**	**0.09**	**5.33**	**.024**	**.07**
	E x O x A	75, 1		3.46	.067	.04
Follow up 1.2: T = 1500 ms	**A**	**75, 2**	**0.04**	**29.18**	**< .001**	**.28**
	E	**75, 1**	**0.20**	**10.49**	**< .001**	**.12**
	E x A	75, 1		2.28	.135	.03
	O	**75, 1**	**0.02**	**77.19**	**< .001**	**.51**
	O x A	75, 1		0.05	.827	< .01
	E x O	75, 1	0.02	0.81	.371	.01
	E x O x A	75, 1		0.55	.459	< .01
Follow up 2.1: T = 1000 ms; O = First	**A**	**75, 1**	**0.03**	**18.69**	**< .001**	**.20**
	E	75, 1	0.02	0.37	.545	< .01
	E x A	75, 1		0.593	.444	< .01
Follow up 2.2: T = 1000 ms; O = Second	**A**	**75, 1**	**0.02**	**27.22**	**< .001**	**.27**
	E	**75, 1**	**0.02**	**14.61**	**< .001**	**.16**
	E x A	75, 1		3.21	.077	.04

Note. A = age group (young vs. older adults); E = encoding strategy (pointing vs. observation only); T = display time (1000 ms vs. 1500 ms); O = order (test stimulus is first vs. second array). Significant effects are printed in boldface.

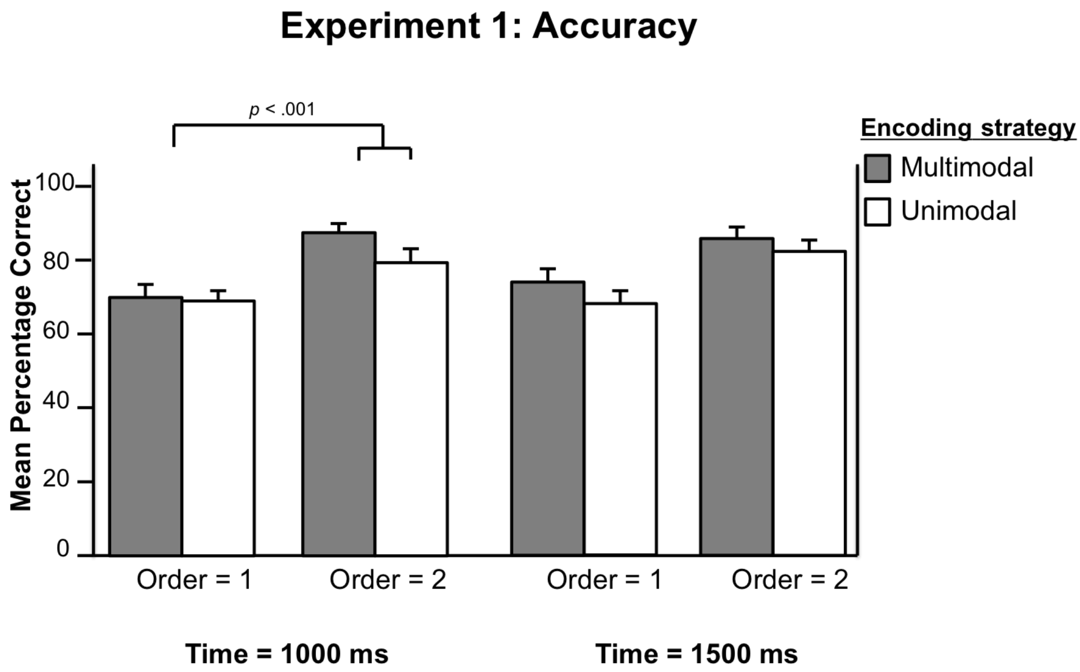


Figure 2. Interaction between encoding strategy, time and order revealed that participants performed better on multimodally than unimodally encoded arrays, if the second array was tested and the display time was 1000ms.

Although there was no interaction with age group, we felt it would be relevant to conduct an exploratory follow-up analysis within the young adult group, because Chum et al. (2007), who had young adult participants and a 1000 ms figure display time, found only main effects of encoding strategy (multimodal > unimodal) and order (2^{nd} array tested > 1^{st}), but no interaction. Consequently, the question is whether the interaction between encoding strategy and order found in the 1000ms presentation time trials was somehow caused by the inclusion of an older adult group in this study. This exploratory analysis would allow us to find out whether or not we replicated the findings by Chum et al. regarding the young adults. Similar to the study by Chum et al., analysis of the young adults' performance showed main effects of encoding strategy and order; no other effects were found (see Table 2B). Although we have to be cautious because age group did not significantly interact with other factors, this suggests that the interactions discussed above were mainly caused by the inclusion of an older adult group in the present study.

Table 2B.

Statistics of the Analysis on Performance Accuracy of the Young Adults in Experiment 1

Analysis	factor(s)	*df*	*MSE*	*F*	*p*	η_p^2
Young Adults	**E**	**38, 1**	**0.02**	**4.99**	**.032**	**.12**
E x T x O	T	38, 1	0.02	0.70	.408	.02
	O	**38, 1**	**0.02**	**95.05**	**< .001**	**.71**
	E x T	38, 1	0.02	0.10	.751	< .01
	E x O	38, 1	0.02	0.02	.889	< .01
	T x O	38, 1	0.01	0.42	.523	.01
	E x T x O	38, 1	0.01	0.11	.744	< .01

Note. E = encoding strategy (pointing vs. observation only); T = display time (1000 ms vs. 1500 ms); O = order (test stimulus is first vs. second array). Significant effects are printed in boldface.

Reaction time

The analysis of the reaction time data showed main effects of encoding strategy (multimodal < unimodal), time (1000 ms display time < 1500 ms display time), order (2^{nd} array test-relevant < 1^{st} array test-relevant), and age (young < older adults). No interaction effects were found (see Table 3).

Table 3.

Statistics of the Analysis on Reaction Times in Experiment 1

Analysis	factor(s)	*df*	*MSE*	*F*	*p*	η_p^2
Omnibus Test	**A**	**75, 1**	**1129431.82**	**12.31**	**.001**	**.14**
E x T x O x A	**E**	**75, 1**	**176084.96**	**0.10**	**.003**	**.11**
	E x A	75, 1		0.10	.765	.01
	T	**75, 1**	**187325.91**	**4.75**	**.032**	**.06**
	T x A	75, 1		1.55	.216	.02
	O	**75, 1**	**237036.63**	**77.33**	**< .001**	**.51**
	O x A	75, 1		0.41	.522	< .01
	E x T	75, 1	102919.18	0.02	.881	< .01
	E x T x A	75, 1		0.37	.547	< .01
	E x O	75, 1	159377.15	1.74	.191	.02
	E x O x A	75, 1		2.14	.147	.03
	T x O	75, 1	96136.12	0.13	.722	< .01
	T x O x A	75, 1		0.40	.529	< .01
	E x T x O	75, 1	88014.38	0.67	.416	< .01
	E x T x O x A	75, 1		0.05	.824	< .01

Note. A = age group (young vs. older adults); E = encoding strategy (pointing vs. observation only); T = display time (1000 ms vs. 1500 ms); O = order (test stimulus is first vs. second array). Significant effects are printed in boldface.

Discussion

Experiment 1 showed that aging was indeed associated with declines in working memory performance. Young adults performed significantly better and faster on the present visuospatial working memory task than older adults. We suggest that age-related declines in working memory capacity can explain this effect of age. More interesting, for both age groups, a multimodal encoding strategy led to better and faster performance than a unimodal strategy. Also, both age groups performed better on trials in which the second compared with the first array of figures was tested. Although these main effects seemed to be qualified by an interaction between encoding strategy and order, it should be noted that this interaction was only found in the trials in which each figure in an array was presented for 1000 ms and not 1500 ms, and that this interaction was no longer found in the exploratory analysis of only the young adults' performance. Thus, this interaction only seems to be present when the older adults are included in the analysis and only for one of the presentation times. Consequently, caution is warranted not to over-interpret the interaction effects of Experiment 1. Overall, our results replicate those by Chum et al. (2007) and additionally show that these findings also extend toward older adults. To the best of our knowledge, this is the first study showing that pointing can enhance older adults' visuospatial working memory performance.

Experiment 2

Experiment 2 investigated whether cueing relevance could decrease the effect or order found in Experiment 1 and could add to the effect of multimodal encoding. This was inspired by a study of Cansino et al. (2011) who showed that cueing relevance *before* information encoding (access function; Hasher et al., 1999) facilitates visuospatial working memory performance in young and older adults and cueing *after* encoding (deletion function; Hasher et al., 1999) facilitates visuospatial working memory performance only in young adults.

Participants

Participants were 32 young adults (21 women, 11 men, M_{age} = 19.8 years, SD = 1.5, age range 17–23 years), and 26 older adults (17 women, nine men, M_{age} = 65.4 years, SD = 3.4 age range 60–71 years). The recruitment procedure and reward of the participants were identical to those of Experiment 1.

Materials and procedure

Experiment 2 used the same materials and procedure as Experiment 1, except for some changes. First, only a display time of 1000 ms was used. Second, we added a condition in which participants received a cue before or after the stimulus presentation, indicating which of the arrays (the circles or the squares) would be tested. Note that the presentation of the cue caused a time delay of 1000 ms extra time between encoding and test phase in the deletion condition, and between the trial onset and the encoding phase in the access condition. To keep the trial structure equal, we added a white screen presented for 1000 ms after the encoding phase in the access condition, and before encoding in the deletion condition.

Results

Accuracy and reaction time data were analyzed with a mixed 2 x 2 x 2 x 2 ANOVA with within-subjects factors encoding strategy (multimodal vs. unimodal), order (first vs. second array was relevant), and cue position (before vs. after the encoding phase), and between-subjects factor age group (young vs. older adults). All means and standard deviations of the accuracy (%) and reaction times (ms) data of Experiment 2 can be found in Table 4. As in Experiment 1, only the significant effects are discussed here, statistics of the analyses of Experiment 2 can be found in Table 5 (accuracy) and 6 (reaction times).

Table 4.

Means (and SD) of Accuracy (Acc) and Reaction Times (RT) in Experiment 2

			Young Adults (*n* = 32)				Older Adults (*n* = 26)			
			Cue before		Cue after		Cue before		Cue after	
	Order		*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Pointing	1st	Acc (%)	85.07	13.97	77.93	13.24	83.17	14.55	74.04	18.00
	1st	RT (ms)	822	417	1378	1008	966	289	1174	355
	2st	Acc (%)	90.35	9.33	91.61	12.05	87.02	10.89	86.54	12.21
	2st	RT (ms)	664	251	639	301	1017	298	1024	333
Observing	1st	Acc (%)	80.93	13.43	79.30	16.12	74.04	17.29	73.08	17.21
	1st	RT (ms)	767	305	713	295	1230	430	1175	474
	2st	Acc (%)	91.67	10.90	87.33	13.39	82.21	19.42	76.92	19.27
	2st	RT (ms)	602	239	658	316	1124	407	1213	427

Accuracy. The analysis of the accuracy data revealed main effects of encoding strategy (multimodal > unimodal), order (2nd array tested > 1st), cue (before > after), and age group (young > older adults). Interactions were found of encoding strategy and age group and of encoding strategy, order, and cue. No other interactions were statistically significant (see Table 5; Omnibus test).

Table 5.
Statistics of the Analyses and Follow-Up Analyses on Performance Accuracy in Experiment 2

Analysis	factor(s)	*df*	*MSE*	*F*	*p*	η_p^2
Omnibus Test	**A**	**56, 1**	**0.05**	**7.88**	**.007**	**.12**
E x O x C x A	**E**	**56, 1**	**0.01**	**11.91**	**.001**	**.18**
	E x A	**56, 1**		**4.61**	**.036**	**.08**
	O	**56, 1**	**0.02**	**38.39**	**< .001**	**.41**
	O x A	56, 1		0.77	.384	.01
	C	**56, 1**	**0.02**	**6.56**	**.013**	**.11**
	C x A	56, 1		0.14	.712	< .01
	E x O	56, 1	0.01	0.27	.602	< .01
	E x O x A	56, 1		0.15	.634	< .01
	E x C	56, 1	0.01	0.14	.711	< .01
	E x C x A	56, 1		0.15	.697	< .01
	O x C	56, 1	0.02	0.99	.323	.02
	O x C x A	56, 1		0.02	.892	< .01
	E x O x C	**56, 1**	**0.02**	**5.52**	**.022**	**.09**
	E x O x C x A	56, 1		0.03	.855	< .01
Follow up 1.1: A = Young	E	31, 1	0.01	1.06	.311	.03
Follow up 1.2: A = Older	**E**	**25, 1**	**0.02**	**12.57**	**.002**	**.34**
Follow up 2.1: E = Multimodal	A	57, 1	< 0.01	3.44	.069	.06
Follow up 2.2: E = Unimodal	**A**	**57, 1**	**0.01**	**8.99**	**.004**	**.14**

Note. A = age group (young vs. older adults); E = encoding strategy (pointing vs. observation only); O = order (test stimulus is first vs. second array); C = cue (before vs. after encoding). Significant effects are printed in boldface.

The encoding strategy and age group interaction was further explored by conducting repeated measures ANOVA for each age group separately, with encoding strategy as within-subjects factor and ANOVAs for each encoding strategy separately with age group as between-subjects factor, with an adjusted alpha level of .05/4.

The analysis of the young adults' performance data showed no effect of encoding strategy; that is, for young adults, pointing no longer had a beneficial effect compared with observation only (see Table 5; Follow up 1.1). In contrast, the analysis of the older adults' performance data did show an effect of encoding strategy; older adults were more accurate in the multimodal than the unimodal encoding condition (see Table 5; Follow up 1.2). The analysis of the young and older adults performance accuracy in the multimodal encoding condition revealed that older adults' performance was equal to that of the young adults (see Table 5; Follow up 2.1), while their performance was lower than that of the young adults in the unimodal encoding condition (see Table 5; Follow up 2.2).

Looking at the data in Table 4, the interaction of encoding strategy, order and cue, seems to indicate that averaged over both age groups; there was a beneficial effect of multimodal encoding in the *access* condition when the *first* array was tested, and in the *deletion* condition when the *second* array was tested. Multiple comparisons with an adjusted alpha level of .05/4 confirmed this (see Figure 3).

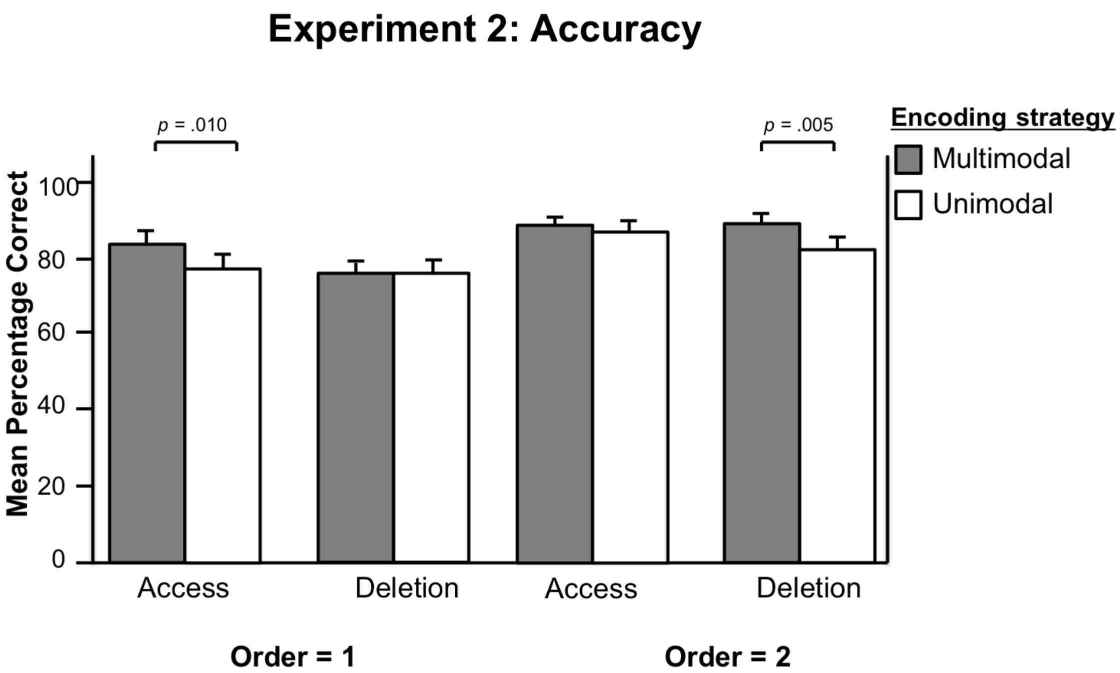


Figure 3. Interaction between encoding strategy, order and cue revealed an effect of encoding strategy in the access condition when the first array was tested, but not the second array was tested. In contrast, in the deletion condition encoding strategy had an effect when the second but not the first array was tested.

Encoding strategy had an effect in the access condition when the first array was tested (with multimodal encoding, M = 84.22, SD = 14.14, outperforming unimodal encoding, M = 77.84, SD = 15.53, p = .010), but not when the second array was tested (multimodal: M = 88.86, SD = 10.10; unimodal: M = 87.43, SD = 15.89, p = .475). In contrast, in the deletion condition encoding strategy had an effect when the second array was tested (with multimodal encoding, M = 89.33, SD = 12.28, outperforming unimodal encoding M = 82.51, SD = 16.96, p = .005), but not when the first array of figures was tested (multimodal: M = 76.18, SD = 15.53; unimodal M = 76.51, SD = 16.76, p = .891).

Reaction time. The analysis of the reaction time data showed a main effect of encoding strategy, order, and age, but not of cue. Significant interaction effects were found for encoding strategy and age group, and encoding strategy, cue, and age group. No other interaction effects were significant (see Table 6; Omnibus test).

Table 6.
Statistics of the Analyses and Follow-Up Analyses on Reaction Times in Experiment 2

Analysis	Factor(s)	*df*	*MSE*	*F*	*p*	η_p^2
Omnibus Test	**A**	**56, 1**	**399481.85**	**51.35**	**< .001**	**.12**
E x O x C x A	**E**	**56, 1**	**84950.62**	**5.21**	**.026**	**.18**
	E x A	**56, 1**		**8.23**	**.006**	**.08**
	O	**56, 1**	**80998.14**	**7.53**	**.008**	**.41**
	O x A	56, 1		1.41	.241	.01
	C	56, 1	110623.27	0.12	.735	.11
	C x A	56, 1		2.80	.100	.05
	E x O	56, 1	58723.72	< .01	.957	< .01
	E x O x A	56, 1		0.09	.766	< .01
	E x C	56, 1	53473.18	< .01	.958	< .01
	E x C x A	**56, 1**		**4.16**	**.046**	**.07**
	O x C	56, 1	75667.92	0.69	.408	.01
	O x C x A	56, 1		1.96	.167	.03
	E x O x C	56, 1	69486.06	2.91	.094	.05
	E x O x C x A	56, 1		3.24	.077	.06
Follow up 1.1: C = 1	E	56, 1	33166.53	3.46	.068	.06
	A	56, 1	**125463.29**	**31.45**	**< .001**	**.36**
	E x A	**56, 1**		**12.89**	**.001**	**.19**
Follow up 1.2: C = 2	E	56, 1	36045.37	2.96	.091	.05
	A	**56, 1**	**129589.27**	**49.89**	**< .001**	**.47**
	E x A	56, 1		0.92	.341	.02
Follow up 2.1: C = 1; A = Young	E	31, 1	31984.23	1.73	.198	.05
Follow up 2.2: C = 1; A = Older	**E**	**25, 1**	**34632.58**	**12.88**	**.001**	**.34**

Note. A = age group (young vs. older adults); E = encoding strategy (pointing vs. observation only); O = order (test stimulus is first vs. second array); C = cue (before vs. after encoding). Significant effects are printed in boldface.

The interaction of encoding strategy, cue, and age group was further explored by conducting repeated measures ANOVAs for each cueing condition separately, with encoding strategy as within-subjects factor and age group as between-subjects factor and an adjusted alpha level of .05/2. Analysis of the trials in the access condition revealed no effect of encoding strategy, an effect of age group (young > older), and an interaction between encoding strategy and age group (see Table 6; follow up 1.1). We further explored this interaction between encoding strategy and age group by conducting a repeated measure ANOVA for each age group separately with encoding strategy as within-subjects factor. These analyses revealed an effect of encoding strategy in older adults (see Table 6; follow up 2.1), but not young adults (see Table 6; follow up 2.2). These results reflect that in the access condition, the older but not the young adults, were faster in recognizing the multimodally than unimodally encoded arrays.

Analysis of the trials in the deletion condition revealed no effect of encoding strategy, an effect of age group (young > older), but no interaction between encoding strategy and age group (see Table 6; follow up 1.2). These results showed that on trials with cues presented after encoding, young adults were faster to respond than older adults.

Discussion

In Experiment 2, the effect of encoding strategy was no longer present in young adults, presumably because they adopted a different learning strategy than in Experiment 1 in response to the cues provided. For older adults, however, there still was a beneficial effect of pointing. In fact, they performed equally well as the young adults in the multimodal encoding condition, but more poorly in the unimodal encoding condition. We will elaborate more on this finding in the general discussion.

For both age groups, it was found that in the access condition, a multimodal compared with a unimodal encoding strategy led to better performance when the first array was tested, bringing performance up to the level of that on trials in which the second array was tested. This suggests that in combination with cueing before encoding, pointing can ameliorate the negative effect of temporal decay in visuospatial working memory. In the deletion condition on the other hand, pointing had a beneficial effect only when the second array was tested, which is in line with the interaction found in Experiment 1, which also showed a positive effect of multimodal over unimodal encoding when the second array was task relevant. These results seem to support our hypothesis that the effect of temporal lag between encoding and test can be ameliorated by making use of the access function (i.e., cueing).

General discussion

The present study aimed to replicate the findings by Chum et al. (2007) that pointing facilitates visuospatial working memory in young adults and to investigate whether any positive effects also apply to older adults (Experiment 1). Second, it was investigated whether cueing would influence the effect of time lag between encoding and test phase on performance (Experiment 2).

The main finding in Experiment 1 was that we replicated the findings of Chum et al. (2007) who showed that a multimodal compared with a unimodal encoding strategy led to better visuospatial working memory performance in young adults, and that we extended their findings by showing that this effect also applies to older adults. In line with previous evidence showing age-related declines in working memory functioning (e.g., Salthouse & Babcock, 1991), Experiment 1 showed that young adults outperformed older adults in general. This effect might possibly arise because of older adults' lower working memory capacity meaning that they could not maintain information from the first array active long enough. The main finding in Experiment 2 was that cueing relevance in combination with a multimodal encoding strategy improved older adults' performance, bringing it up to the same level as that of young adults. Moreover, in both experiments we replicated the finding that arrays presented second compared with first, were better recognized, which Chum et al., called 'a typical effect of temporal proximity between the encoding and test phase'. However, we noticed that the size of the time lag between encoding and test in this paradigm is related to the number of stimuli that are between the encoding and test phase. Thus if the temporal proximity is low (when the first array is tested), this means that it takes not just more time until the information is tested during which it has to be rehearsed, but there is also more information being presented in that time. This information needs to be processed while simultaneously rehearsing the previously presented information, which places a high load on working memory and might interfere with the maintenance of the first array in working memory. These findings suggest that it is working memory load, rather than temporal proximity only, that was responsible for the finding that memory performance was better on the arrays presented last in both Chum et al. and Experiment 1.

In Experiment 2, the finding that performance in the multimodal encoding condition was similar for both young and older adults, but the performance of older adults was lower than that of the young adults in the unimodal encoding condition, suggests that the simple act of pointing during the encoding of stimulus locations can compensate for age-related declines in working memory performance we found in Experiment 1. To explain this result we suggest that in line with the selection-for-action hypothesis proposed by Allport (1989) pointing aids selective attentional processes during encoding. Selective attention has been associated to working memory and even said to influence working memory performance (Gazzaley & Nobre, 2012). Top-down cognitive control, is proposed to underlie selective attention and working memory performance (Gazzaley & Nobre, 2012) and is found to decline with aging (Egner & Hirsch, 2005). Cognitive control is an internal system in the brain, located in the prefrontal areas that signals and amplifies task-relevance, that is, cognitive control functions are found to modulate the neural activity in sensory areas depending on the relevance of a stimulus (Egner & Hirsch, 2005). We suggest that in our study pointing toward the stimulus locations compensated for age-related declines in working memory and selective attention (as visible in older adults' performance in the unimodal condition), because it served as an external control system, guiding attention.

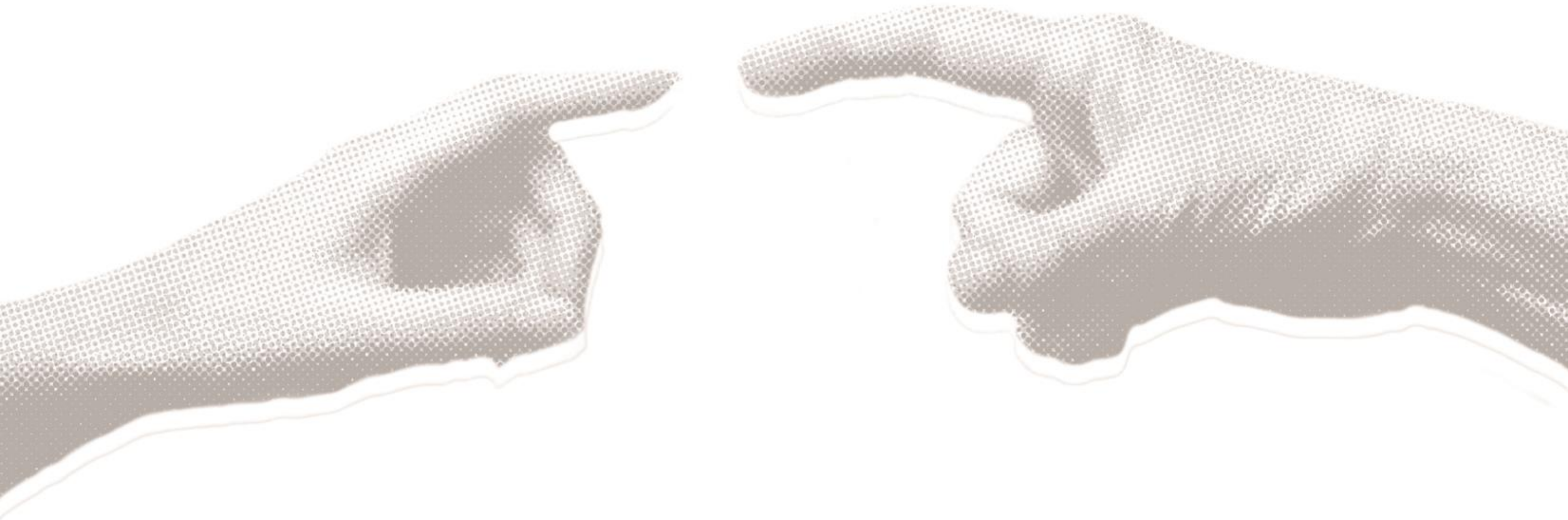
A second explanation comes from Geary (2008, 2012), who state that there are two kinds of knowledge named biologically primary and secondary knowledge. Biologically primary knowledge consists of information that humans have evolved to process and understand automatically, including action and action understanding (and imitation; Paas & Sweller, 2012). In contrast, biologically secondary knowledge is only gained by explicit learning, which demands effort and conscious cognitive processing. Because pointing is action, this would be a rather effortless (requesting little to no working memory capacity) manner to add an extra memory code via which retrieval can occur.

A limitation of the study is that from the results, we cannot disentangle the individual effects of pointing and cueing. However, the present study focused on replicating the effect of pointing on young adults' visuospatial working memory and finding out whether a similar effect would be present in older adults (Experiment 1). Furthermore it was investigated whether the claim made by Chum et al. (2007) that the effect of order in the present paradigm was caused by the temporal delay (Experiment 2) or whether the interference of the irrelevant array entering working memory also influenced performance. Therefore we added the cues to the present paradigm. Nevertheless, it would be an interesting idea for future research to investigate the effect of cues and pointing separately on visuospatial working memory. In addition would also be interesting to purely vary the temporal decay (without presenting interfering stimuli) between encoding and test in a similar paradigm and to find out whether the effect of cueing would still be present.

In sum, the present study showed that a multimodal compared with a unimodal encoding strategy improved visuospatial working memory performance in both young and older adults (Experiment 1) and that adding visual cues to the multimodal but not the unimodal encoding strategy improved the level of older adults' visuospatial working memory performance to that of young adults. Furthermore, we showed that a multimodal encoding strategy together with predictive visual cues can ameliorate the effect of temporal lag on working memory in both young and older adults. These findings are especially interesting from an aging perspective, because they suggest that (at least, in the present paradigm) gestures and visual cues can be used as tools to compensate for age-related declines in visuospatial working memory performance.

Chapter 7

Summary and discussion



Summary and discussion

The studies presented in this dissertation aimed to investigate whether observing or producing deictic gestures (i.e., pointing and tracing gestures to index a referent in space or a movement pathway), could facilitate memory and learning in children, young adults, and older adults. More specifically, regarding memory it was investigated whether the use of deictic gestures would improve performance on tasks targeting cognitive functions that are found to change with age (working memory, cognitive control, and source memory). In addition, it was investigated whether any found effects would be more pronounced for children in whom these cognitive functions are still developing, and for older adults, in whom these cognitive functions have been found to suffer from age-related declines.

The first part of this dissertation presented studies investigating the effect of observing deictic gestures made by a human model during instruction of a problem-solving task on children's, young adults' and older adults' learning (Chapter 2) and young adults' visual attention (Chapter 3). The second part presented studies investigating the effect of making deictic gestures during encoding on spatial source memory in young and older adults (Chapter 4) and in children and young adults (Chapter 5), as well as on visuospatial working memory in young and older adults (Chapter 6).

First, the main findings from both parts will be summarized, then the theoretical and practical relevance of these findings will be discussed, and finally, directions for future research in this area will be outlined.

Summary of the main findings

Part 1

The studies reported in Part 1 investigated whether observing deictic gestures made toward the task by an instructor in video-based modeling examples would positively affect students' attention allocation and learning. **Chapter 2** presented three experiments that investigated children's (Experiment 1), young adults' (Experiment 2), and older adults' (Experiment 3) learning of a novel problem-solving task from observing a video-based modeling example in which an instructor (the model) demonstrated and explained how to solve the problem. The video example was based on a typical modern lecture setting, in which the model stood next to a whiteboard on which the task was displayed. The task used was a computerized version of Luchins' (1942) water jug task (Schmid, Wirth, & Polkehn, 2003). The female model explained the task and depending on the instructional condition, she verbally referred to the task while: (i) making head movements toward the screen (no cue condition –although note that the gaze might have provided a less specific kind of cue, cf. **Chapter 3**), or in addition to those head movements, either (ii) an artificial cue indicated the area of the task that the model referred to on the screen (arrow cue condition), or (iii) she made pointing and tracing gestures to the area(s) she referred to on the screen (gesture cue condition).

First, it was hypothesized that the gesture cue condition would lead to better learning efficiency (reflected in higher performance, lower mental effort and shorter time on task) than the arrow cue condition or no cue condition. Because gestures especially seem to aid learning in complex tasks, that is, if cognitive load is high (Chu & Kita, 2011; Goldin-Meadow, Nusbaum, Kelly & Wagner, 2001; McNeill, Alibali & Evans, 2000), two levels of task complexity (lower and higher) were included. However, because children and older adults have suboptimal functioning of some cognitive properties important for learning novel problem-solving tasks, such as working memory and cognitive control (Crone, Wendelken, Donohue, Van Lijenhorst, & Bunge, 2006; Vecchi, Richardson, & Cavallini, 2005), tasks at both complexity levels were expected to be more difficult for these groups than for young adults. Thus besides an effect of task complexity within groups, also a between group effect was expected in that young adults would outperform children and older adults. Finally, because task complexity would be relatively higher for children and older adults compared with young adults, possible learning gains were also expected to be higher in these groups than in young adults (i.e., the effects of gestures would be larger).

As expected, performance in all age groups was better and mental effort was lower for simple than for complex problems. A typical age effect was found, with young adults outperforming the older adults. In addition, children outperformed older adults. These findings underscore that the search for instructional design methods that can help compensate for age-related impairments in cognitive functioning and improve learning, is especially important for older adults. However, only limited evidence was found for the expected positive effects of gesture cues in instruction. Gesture cues resulted in an advantage within the older adult group on time on task for isomorphic problem solving (i.e., older adults in the gesture cue condition were faster than those in the no cue condition). No other positive effects of observing an instructor's gestures were found in any of the age groups.

In **Chapter 3** a study was presented in which eye tracking was used to investigate whether the gestures made by the instructor in video-based modeling examples, would help learners to focus their attention timely on the task aspects the model referred to. This study used the same water jug modeling examples as the study reported in Chapter 2; however, the instructional conditions were slightly different, with (i) the model looking only straight into the camera (no cue condition), (ii) the model occasionally turning her head to the task display when mentioning an area of the task (gaze cue condition) or, (iii) the model turning her head and pointing at the area of the task she referred to and tracing gestures to show from which to which jug water should be moved (gaze + gesture cue condition). Students' visual attention while studying the examples was recorded using eye tracking. Because human faces and pointing gestures are known to automatically draw people's attention, it was hypothesized that participants in the gaze and especially those in the gaze + gesture cue condition would be better able to switch their attention from the model to the task areas the model was talking about.

A clear trend was found in line with this hypothesis: Students in all instruction conditions spent more time looking (in terms of total fixation duration) at the model than at the parts of the task that the model was referring to in the instruction. It is important to mention that this does not mean they spent more time looking at the model than at the task in general, but they were not looking at the part of the task that the model was referring to. The gaze and gesture cues helped to shift attention away from the model to the task area that she was talking about. That is, students' attention toward the model gradually decreased and the attention toward the specific task area the model was verbally referring to gradually increased from the no cue, to the gaze cue, to the gesture + gaze cue condition. Even though there were no effects on learning (which were not to be expected given the small sample size) these findings suggest that gesture cues are an effective tool to guide students' attention to the right place at the right time while they study video-based modeling examples, which might potentially have beneficial effects on learning.

Part 2

The studies reported in Part 2 investigated whether self-produced pointing gestures toward stimulus locations would enhance source memory (Chapter 4 and 5) and visuospatial working memory (Chapter 6) for these locations. **Chapter 4** presented two experiments, investigating whether or not pointing at picture locations compared with naming (Experiment 1), or only observing them (Experiment 2) during encoding could enhance spatial source memory for picture-location associations in young and older adults. Source memory has been found to decline with aging (Old & Naveh-Benjamin, 2008) and therefore it is important to investigate possible ways to improve this type of memory, especially in older adults. Because pointing gestures are visuospatially oriented (indexing or referring to objects or locations in space) it was hypothesized that pointing would be a suitable encoding strategy for improving spatial source memory. In line with the expectations, the results showed that the pointing encoding strategy led to better source memory of picture locations than the verbal encoding strategy (i.e., naming) or visual observation only in both young and older adults. As expected, older adults performed equally well as the young adults on the item memory test, but were outperformed by the young adults on the source memory test. Pointing did not help compensate for the age-related decline in source memory performance as the beneficial effect of pointing compared with naming and visual observation only was similar in young and older adults.

Chapter 5 described two experiments that investigated whether or not pointing toward picture locations compared with only observing them could enhance spatial source memory in children and young adults. In this study another factor was added: picture-location congruency. A congruent picture location means that the location is consistent with general dominant past experiences with the object or scene in the picture, such as a picture of a cloud presented at the upper half of the screen. A picture of a cloud presented at the lower half of the screen, would be an example of an incongruent picture location. Although both source and item memory functioning are still developing in children, source memory undergoes the biggest changes between childhood and adolescence (Cycowicz, Friedman, Snodgrass, & Duff, 2001). It was hypothesized that pointing during encoding in addition to visual observation only could enhance spatial source memory for picture-location pairs in children (Experiment 1) and young adults (Experiment 2) and that this effect might be larger in children because possible learning gains are higher in this group. Moreover, source memory for congruent picture locations was expected to be higher than source memory for incongruent picture locations. Results showed a clear congruency effect on source memory accuracy for both the children and young adults: participants remembered more locations of pictures presented at congruent locations than locations of pictures presented at incongruent locations. In contrast to the findings from the study reported in Chapter 4, showing that pointing compared with visual observation only had a positive effect on source memory accuracy, this study neither revealed an effect of encoding strategy on source memory performance in young adults, nor children. However, the young adults showed faster response times on the item memory test in the pointing condition. The contrasting results between the study reported in Chapter 4, indicating a positive effect of pointing on spatial source memory, and the study in Chapter 5, revealing no effect of pointing on spatial source memory, might have been caused by the different design of the studies. Whereas a within-subjects design was used in the study described in Chapter 4, a between-subjects design was used in the study described in Chapter 5. This explanation will be further elaborated upon in the Discussion.

In **Chapter 6** two experiments were presented, which investigated whether or not pointing could enhance visuospatial working memory in young and older adults. For this study the visuospatial working memory test of Chum, Bekkering, Dodd, and Pratt (2007) was adopted, in which participants had to remember the locations of simple figures. Participants were presented with a sequence of simple figures consisting of an array of squares and an array of circles, varying from three to five figures per array. Half of the participants were instructed to point at the circles and the other half at the squares. After each stimulus presentation, participants were tested on their visuospatial memory randomly for either the squares or the circles. This means that for accurate performance, the locations of both arrays had to be kept in working memory until the test phase, but only one of the two was relevant. Chum et al. (2007) found a positive effect of pointing compared with observation only on visuospatial working memory performance and a recency effect in that the stimuli presented more closely to the test phase were better remembered than the stimuli presented at a larger temporal distance from the test phase. Moreover, Chum et al. found an interaction between encoding strategy and array size. Specifically, the interaction showed that the beneficial effect of a multimodal encoding strategy declined with increasing array size (i.e., increasing working memory load) and even disappeared for the longest arrays (five circles and five squares). Using only the smallest arrays for which the effect was largest, Experiment 1 aimed to replicate the findings of Chum et al. in young adults and to find out whether they would extend to older adults as well. In line with the hypothesis, Experiment 1 replicated the beneficial effect of pointing and the recency effect found by Chum et al. in both young adults and older adults. The young adults outperformed the older adults (i.e., there was no evidence of pointing compensating for age-related declines). Experiment 2 investigated whether cueing would add to the effect of encoding strategy and whether the recency effect would purely stem from a difference in temporal proximity or also from interference from the irrelevant stimuli (the presentation of the irrelevant second array). It was hypothesized that predictive cues (cueing the relevant stimuli before they were presented) would add to the effect of encoding strategy and could ameliorate the effect of time lag between encoding and test. Indeed, cueing relevance in combination with a pointing encoding strategy improved older adults' performance to the same level as that of young adults. Moreover, cueing prior to encoding in combination with pointing raised performance on trials in which the first array was tested for both young and older adults. This suggests that it is interference of the presentation of the irrelevant array, rather than temporal proximity per se, that was responsible for the effect of order found by Chum et al. and Experiment 1. When cueing after encoding, pointing had a beneficial effect only when the second array was tested, which is in line with the interaction found in Experiment 1 that also showed a positive effect of pointing when the second array was task relevant.

Discussion and directions for future research

Observing gestures as attentional cues in video instruction

Over the past decade, learning from videos in which a human model demonstrates and explains how to complete a certain task, has rapidly gained popularity (e.g., on YouTube). Such video-based modeling examples are increasingly used by learners of all ages, both in formal and informal educational settings. Example-based learning is known to be a very effective type of instruction, especially for novice learners (for a review, see Van Gog & Rummel, 2010). However, video-modeling examples come in many forms, and little is known about design characteristics that make such examples effective in terms of attention guidance and learning (Van Gog & Rummel, 2010).

Many videos recorded by teachers for their students (e.g., wiskundeacademie.nl) show a typical modern classroom situation, in which the teacher (i.e., the model) is standing next to a whiteboard or smartboard on which the learning task that s/he is explaining is visualized. In such a situation, it is possible that the presence of the model creates a type of split-attention effect, because the teacher's face will automatically attract the learners' attention (Tzourio-Mazoyer et al., 2002). The split-attention effect is the adverse effect on learning that is found when students have to divide their attention between, and mentally integrate information from, multiple sources of information (Ayres & Sweller, 2014). However, gaze direction and pointing gestures made by the model could also automatically trigger attention shifts (Sato, Kochiyama, Uono, & Yoshikawa, 2009), which might alleviate the split-attention effect. Therefore, it was hypothesized in Part 1 that gaze and gesture cues might be able to timely guide the learners' attention toward relevant aspects of the learning material and thereby alleviate split attention and foster learning, whereas students who spend more time looking at the model than at what the model is talking about would not be able to smoothly integrate the visual and verbal information provided in the example, which might hamper their learning (see also Mayer & DaPra, 2012; Moreno, Reislein, & Ozogul, 2010). Arguably, such gaze and gesture cues might be even more necessary for children and older adults, because of age-related working memory deficiencies.

However, the studies in Part 1 showed only limited evidence in favor of this hypothesis. Although the detailed analysis of participants' eye movements in the study reported in Chapter 3 indeed seemed to support the hypothesis that gesture plus gaze cues were most effective for guiding students' attention to the right location at the right time, the number of participants in that study was too low to establish whether this would affect learning. The study reported in Chapter 2 did have sufficiently large sample sizes, but yielded only one positive effect of observing gestures on learning: older adults who learned from an instructor who provided gesture and gaze cues toward the task solved isomorphic problems faster than older adults who learned from an instructor who only provided gaze cues at the task. No other effects of gestures were found for the children, young adults and older adults on isomorphic and transfer problem-solving performance and cognitive load.

Although the present paradigm and design proved to be valid in manipulating task complexity and was sensitive enough to detect an effect of age, the results showed almost no effect of gestures, which is not in line with previous studies that did show a positive effect of observing deictic gestures on learning (De Koning & Tabbers, 2013; Valenzeno, Alibali, & Klatzky, 2003) and problem solving (Lozano & Tversky, 2006). This difference might be caused by the type of task used; De Koning and Tabbers (2013) did not look into problem solving and Lozano and Tversky (2006) used a more concrete type of problem solving (assembly of a simple object). In the study of Valenzeno et al. (2003) deictic gestures were used to teach preschoolers about symmetry by pointing at different shapes, which is also a rather concrete task. It is possible that in more abstract problem-solving tasks, such as the water redistribution task used in this study, observing deictic gestures might not influence learning. For example, in the studies reported in Chapter 2 and 3 the deictic gestures pointed at where the learner was supposed to look, but did not reveal additional information about the underlying solution algorithm of the water redistribution task. This might explain why there was an effect of cueing on attention allocation in the study reported in Chapter 3, but not on effects on learning in either Chapters 2 or 3 (although sample size in the study reported in Chapter 3 was too small to draw reliable conclusions from the learning performance).

It is important to mention here that the study reported in Chapter 2 had a different control condition than the study in Chapter 3. In the control condition of the study reported in Chapter 3, the model looked straight into the camera (no gaze or gestures cues) while in the study reported in Chapter 2, the model made head movements (i.e., gaze cues) that – according to the findings in Chapter 3- are already somewhat helpful for guiding attention to the right location at the right time compared with no gaze cues.

In a no cue condition (as in the study reported in Chapter 3), split attention is probably the most extreme. Yet such videos are often used in education (see e.g., wiskundeacademie.nl) and it is possible that a gesture cue condition would lead to better learning than a no cue condition. Future research should therefore replicate the eye tracking results of the study reported in Chapter 3 with a larger sample. This would also allow for more reliable testing whether the attention guidance provided by gaze plus gesture cues would indeed facilitate learning.

A possible problem of the task paradigm used in the studies reported in Chapters 2 and 3 was that it might have restrained variability in performance accuracy. The learning and transfer test both had a fixed amount of problems with a maximum amount of time per problem. From the present data, it seems that performance between instructional conditions did not differ in terms of accuracy. However, because the results suggest that the use of gestures in instruction can speed up older adults' problem-solving performance, it is possible that they could have solved more problems when the test had consisted of solving as many problems as possible within a given amount of time. It is particularly interesting to continue to explore how to improve older adults' learning from video-based modeling examples in future research, because this population is increasingly using online videos (Chen & Persson, 2002). For example, a case study among Canadian older adults (aged > 55) suggests that this group regularly uses instructional videos on learning how to do something at home and videos made by peers and colleagues (video-based modeling examples) (Milliken, O'Donnell, Gibson, & Daniels, 2012).

In conclusion, because the present results did not show the expected positive effects of gestures on learning, it can only be concluded that gestures neither hampered nor improved learning for the problem-solving task used. More research is needed to find out under which conditions gestures in video instructions and other kinds of learning materials can improve learning in populations that might have trouble with existing instructional environments because their working memory is not yet fully developed (children) or has started to decline (older adults).

Effects of self-produced pointing gestures on source memory

The question of whether pointing gestures might enhance source memory for picture-location associations was inspired by research on the enactment effect. This is the robust finding that action phrases that are enacted are better remembered than those only read or heard (Engelkamp, 1998; Feyereisen, 2009; Nilsson, 2000; Zimmer, 2001). According to the multimodal theory of Engelkamp (1998), encoding information in a multimodal fashion using action (by enacting or pantomimic gestures) in addition to vision or sound can enhance source memory for action-object associations. Note that enacting and pantomimic gestures can represent (simulate) specific perceptual and or salient features of the actions and objects and might therefore be very suitable for source memory for action-object associations. Interestingly, pointing gestures are among the most robust gestures in humans, and children already use pointing gestures to index objects and locations before they are able to speak (Iverson & Goldin-Meadow, 2005). Moreover, evidence showed that deictic gestures of a speaker are used to help focus attention on an object in space or a location in a social situation (Bangerter, 2004; Louwerse & Bangerter, 2005; Peeters, Azar, & Özyürek, 2014). Furthermore, pointing toward locations of simple figures has been found to enhance visuospatial working memory (Chum et al., 2007). From these findings it can be inferred that pointing gestures might be especially suitable for the encoding of spatial properties of stimuli, including source memory for object-location associations. Because children and older adults have more trouble with source memory tasks than young adults, it was expected that any effect of pointing would be more pronounced in children and older adults than in young adults.

The results of the study reported in **Chapter 4** showed that self-produced pointing gestures enhanced source memory for picture-location associations in young and older adults. This finding is in line with evidence showing positive effects of actions (including gestures) on source memory for object-action phrases (e.g., Kormi-Nouri & Nilsson, 2001) and action events (Wagner-Cook et al., 2010). In addition, older adults performed as well as the young adults on the item memory test, but more poorly on the source memory test. Although pointing enhanced spatial source memory in young and older adults, such a multimodal encoding strategy did not compensate for the age-related declines in source memory performance.

The results reported in the study in **Chapter 5** did not reveal any positive effects of pointing on source memory. On the item memory test, it was even found that the children in the pointing condition were less accurate on the incongruent trials compared with children in the observation only condition. This effect might have occurred because pointing toward an incongruent compared with a congruent location required additional cognitive control to deal with the interference. Therefore, fewer attentional resources might have been available for encoding of the content of the incongruent stimuli than the congruent stimuli, resulting in lower item memory accuracy in the pointing condition than the observation only condition. This negative effect of pointing was not found for the young adults, probably because they have a more developed cognitive control system. Therefore young adults have less trouble dealing with the interference and pointing toward incongruent picture locations than children, which is in line with research showing that cognitive control processes including interference control are still developing in children (e.g., Bunge, Dudukovic, Thomason, Vaidya, & Gabrieli, 2002).

A contradicting finding was that the results of the study reported in Chapter 4 showed a positive effect of gesturing on spatial source memory, but the results of the study reported in Chapter 5 did not. A potential explanation for these contrasting results is that the studies reported in Chapters 4 and 5 used a different experimental design. In the study described in Chapter 4 a within-subjects design was used and in the study in Chapter 5 a between-subjects design. Which means that in the study in Chapter 4 participants selectively pointed at the locations of some pictures *and* selectively named the locations (Experiment 1) or only observed (Experiment 2) the locations of other pictures. In the study in Chapter 5 participants either pointed at *or* only observed all the pictures. The finding that this difference in experimental design can influence the effects of pointing on spatial memory is supported by a study of Dodd and Shumborski (2009). These researchers used a visuospatial working memory paradigm of Chum et al. (2007), in which participants had to remember the locations of a sequence of simple figures consisting of two arrays (i.e., an array of circles and an array of squares). In the original paradigm, participants had to point to the locations of one array (e.g., the circles) *and* only observe the other (e.g., the squares) within one trial. Chum et al. found that the locations of the pointed figures were better remembered than the ones only observed. However, Dodd and Shumborski found that using a design that requested participants to point at *or* observe all stimuli within one trial, reversed the effect, in that memory for the locations of the observed figures was superior to that of the pointed figures. The authors suggested that the positive effect of pointing might depend on the task demands during encoding; if the task requires a selection process for a subset of the stimuli, pointing facilitates further processing and memory for this subset. In the context of the selection-for-action hypothesis (Allport, 1989) this would mean that selection for action creates an attentional bias toward objects that require action, but that a difference in memory performance can only be detected when participants have to selectively point at versus observe the stimuli during encoding.

This would also explain the positive effects of pointing found in the study reported in Chapter 4, in which a within-subjects design was used. The study in Chapter 5 did not require such a selection process, because a between-subjects design was used. Although Dodd and Shumborsky (2009) investigated a different type of memory (visuospatial working memory) than the studies in Chapters 4 and 5 (spatial source memory), this “selectivity account” can be considered a likely explanation for the present results. The reason why this selectivity influences the results is because the depth of processing may differ between an encoding phase in which different responses to subsets of stimuli need to be selected during encoding (point to one type of stimuli and only observe or name the other type) and an encoding phase with only one encoding strategy. This selective character of the encoding phase in a within-subjects design required participants to process the content of the pictures at least at a semantic level; participants had to decide whether the picture contained a natural or an artificial object (Chapter 4). However, the nonselective character of the encoding phase in a between-subjects design does not require the content of the pictures to be processed at a semantic level. This could mean that the contents of the pictures were processed deeper in the encoding phase in the study reported in Chapter 4 than the study reported in Chapter 5. From this it can be inferred that source memory in itself relies on the quality of the content and the source encoding and that any effect of self-produced pointing gestures on visuospatial source memory only has a fair chance if the pictures are sufficiently encoded.

Taking the above mentioned perspective, a possible explanation for the beneficial effect of selective pointing compared with selective naming or observation only on source memory can be found in research showing that during encoding attentional control processes play an important role in source memory performance (Anderson, Craik, & Naveh-Benjamin, 1998). It has been found that source memory is negatively affected by increased demands on cognitive control functions, such as attentional processes, during encoding but not retrieval (Anderson et al., 1998). Anderson et al. (1998) compared source memory performance in a full attention condition (single task performance) with source memory performance in a divided attention condition (dual task performance), in which a secondary task was either performed during the encoding or retrieval phase. It was found that memory performance only suffered in the divided attention condition during the encoding phase. Older adults seem to have a disadvantage compared with young adults (Anderson et al., 2000) in the functioning of these attentional processes. Anderson et al. (2000) showed that young adults’ source memory performance in a divided attention condition is comparable with that of older adults in a full attention condition.

Other evidence shows that performance on all kinds of cognitive control tasks improves if stimuli are perceived near the hands, for example tasks targeting spatial attention (Reed, Grubb, & Steele, 2006), visual working memory (Tseng & Bridgeman, 2011) and executive functioning (Weidler & Abrams, 2014). These findings can be explained by the selection-for-action hypothesis (Allport, 1989), which proposed that action intentions toward objects, increases attention for these objects, compared with objects without action intentions. From these findings, it can be suggested that the act of pointing toward object locations compared with naming them or only observing them, enhances spatial source memory, because of the attentional bias for objects that elicit action intentions (Allport, 1989) and the positive effect of proximity between the participant's hand and the to be encoded stimuli on cognitive control (e.g., Weidler & Abrams, 2014). Moreover, enhancing this attention and cognitive control might be especially important for older adults because research showed that these attentional and cognitive control processes (e.g., Braver & Barch, 2002) decline with aging and that this is especially problematic for the encoding phase in source memory tasks (e.g., Anderson et al., 1998, 2000).

Despite the fact that these explanations are plausible accounts for *why* pointing enhanced source memory performance in the study reported in Chapter 4, they do not explain *how* this works, in terms of an underlying mechanism. Neuroscientific research might provide insights into such underlying mechanisms. Several brain imaging studies showed that objects that are only perceived are differently processed in the brain than objects we intend to act upon. In this respect, two systems guiding visual attention are distinguished, namely the dorsal stream for "vision for action" (processing "where" and "how" information important for source memory) and the ventral stream for "vision for perception" (processing "what" information important for item memory; e.g., Boussaoud, di Pellegrino, & Wise, 1995; Goodale & Milner, 1992; Milner & Goodale, 2008). In the dorsal stream, visual information in early visual areas (primary visual cortex) is projected to the posterior parietal cortex (Goodale & Westwood, 2004), an area known to be involved in the online coordination and control of visually guided motor acts ("how"; Goodale & Milner, 1992) and the encoding of spatial information ("where"; Khader, Burke, Bien, Ranganath, & Rösler, 2005). The ventral stream projects visual information from early visual areas to the occipito-temporal cortex, and underlies conscious visual perception and the formation of detailed object representations needed for cognitive processes such as recognition and identification (Goodale & Westwood, 2004). Interestingly, a study of Khader et al. (2005) showed a specific involvement of the parietal cortex (the projectory site of the dorsal stream) in source memory linking word pairs to locations, but not for source memory linking word pairs with pictures of faces. In explaining the present findings, it is possible that the pointed pictures in the study reported in Chapter 4 might have been processed via the dorsal stream and pictures of which locations were named or only observed via the ventral stream. Because evidence suggests that the parietal cortex is also involved in source memory for locations (Khader et al., 2005) and action control (Goodale & Milner, 1992), this mechanism may also underlie the positive effect of self-produced pointing during the encoding of picture locations.

Future research should investigate whether or not the need for selection in the study reported in Chapter 4 moderates the effect of pointing on spatial source memory. This can be done by comparing findings from a within-subjects design in which participants point *and* observe, to a between-subjects design in which participants either point *or* only observe picture locations. In addition, although the ventral-dorsal account sounds theoretically plausible, caution is required when using this explanation, because in the study reported in Chapter 4 no brain-imaging techniques were used to measure the involvement of the dorsal and ventral stream. Therefore, more evidence is needed to test this potential explanation by adding neuropsychological evidence to the present behavioral results to investigate the recruitment of the dorsal and the ventral stream during encoding and retrieval of pointed compared with named picture-location associations. In conclusion, pointing at an item's location led to higher spatial source memory performance than visual observation when participants had to selectively point at a subset of the pictures, but not when they did not need to select a response (to point or observe all stimuli).

Effects of self-produced pointing gestures and visual cues on visuospatial working memory

Healthy aging has been associated with declines in working memory functioning (e.g., Salthouse & Babcock, 1991), cognitive speed (Salthouse, 1996, 2000), and interference control (e.g., Houx, Jolles, & Vreeling, 1993; Stolzfus, Hasher, Zacks, Ulivi, & Goldstein, 1993). Consequently, it is important for older adults' functioning to find strategies to compensate for these age-related cognitive declines. Interestingly, a study of Chum et al. (2007) showed that visuospatial working memory for figure locations that were manually pointed at during encoding was better than that for figure locations that were only visually observed. In addition, it was found that the stimuli presented in close temporal proximity to the test phase were better remembered than stimuli presented at a larger temporal distance to the test phase. In Chapter 6, Experiment 1 replicated the results of Chum et al. in young and older adults. However, the young adults outperformed the older adults. This suggests that pointing alone did not compensate for age-related declines in visuospatial working memory (Experiment 1).

Inspired by a study of Cansino, Guzzon, Martinelli, Barollo and Casco (2011) who showed that visual cueing can enhance visuospatial working memory in young and older adults, Experiment 2 investigated whether visual cueing would add to the effect of encoding strategy and could ameliorate the effect or temporal lag in young and older adults. Results of Experiment 2 showed that cueing relevance in combination with pointing improved older adults' performance, bringing it up to the same level as that of young adults. This is a very important finding, because it suggests that gestures together with visual cues can be used as tools to compensate for age-related declines in visuospatial working memory performance (at least, in the present paradigm). In addition, Experiment 2 showed that in the more challenging trials (with the largest time lag and interference of new stimuli) pointing in combination with cueing before encoding can ameliorate the negative effect of temporal lag in visuospatial working memory in both age groups. This suggests that the effect of order is not solely an effect of time lag, but also of interference of the content of the second array. In addition, cueing added to the effect of encoding strategy in older adults, probably because working memory was more challenged in this group. Note that Chum et al. (2007) also showed that the effect of pointing increased with decreasing demands on working memory. Cueing relevance in Experiment 2 might have decreased working memory load and as a result, increased the effect of pointing in older adults. An interesting idea for future studies would be to investigate the effect of cueing without the pointing manipulation to be able to extract the pure effect of cueing.

Conclusions and implications

Overall, the effects of deictic gestures on learning and memory were mixed. The studies in Part 1 showed that observing a video model's deictic gestures had only a small positive effect on time on task for the older adults, but not for the children and the young adults. The studies in Part 2 showed that producing deictic gestures had a positive effect on visuospatial source- and working memory in young and older adults, but only if gesturing or not gesturing (naming or observation only) was manipulated within subjects and not between subjects.

Mixed results of studies investigating effects of deictic gestures on learning are not uncommon; some studies show a positive effect of deictic gestures on learning (e.g., De Koning & Tabbers, 2013; Hu, Ginns, & Bobis, 2015; Macken & Ginns, 2014; Valenzeno, Alibali, & Klatzky, 2003) while others found a negative effect (e.g., Post, Van Gog, Paas, & Zwaan, 2013, for children with lower levels of language ability), no effect (Craig, Gholson, & Driscoll, 2002; Post et al., 2013, for children with higher levels of language ability) or mixed results (e.g., Baylor & Kim, 2009). Note that some of these studies investigated children's learning (Hu et al., 2015; Post et al., 2013; Valenzeno et al., 2003), while others investigated young adults' learning (Baylor & Kim, 2009; Craig et al., 2002; De Koning & Tabbers, 2013; Macken & Ginns, 2014). However, to the best of my knowledge, no research has been conducted yet on the effects of deictic gestures on older adults' memory and learning in itself or in comparison with other age groups.

Because the studies in Part 1 did not show the expected positive effects of gestures on learning outcomes, it can only be concluded that observing deictic gestures neither hampered nor improved learning compared with no gestures or symbolic cues for the particular problem-solving task used. Although no positive effects of gestures on learning from a video-modeling example were found, it must be noted that the specific task used in the studies reported in Chapters 2 and 3 might perhaps not have been sensitive to the instruction conditions used.

An alternative explanation for the null result can be found in the design of the studies. For example, in the study of Hu et al. (2015) and Macken and Ginns (2014) no video-based modeling examples or any other form of animations were used, but participants received written instructions to point and trace themselves in worked examples. The studies of De Koning and Tabbers (2013) and Valenzeno et al. (2003) were more comparable with the present studies because they used an animation with pointing and tracing gestures as cues (De Koning & Tabbers, 2013) or a video instruction with a human model using pointing and tracing gestures (Valenzeno et al., 2003). However, these studies used one instruction that was only shown once to the participants, while in the studies presented in Part 1 of this dissertation multiple videos were used. In the study presented in Chapter 2, participants received a 180 s instruction about the general task rules followed by four video-based worked examples that partly overlapped in problem structure. In the study presented in Chapter 3, participants received one video-based modeling example, twice. It is possible that the five videos shown in the study presented in Chapter 2 covered the information to such an extent that the gestures did not add to the learning anymore and that the repetition of the worked example in the study presented in Chapter 3 caused any learning effect after watching the video the first time to disappear. In addition, the videos all had durations between 90 s and 180 s (180 s for the general instruction, 90 s for the two-step problems and 120 s for the three step problems). If the effect of gesturing is short-lived, the length of the videos might also have induced a decay of any possible effects during the test.

The effects gestures can have on memory and learning may vary depending on types of tasks, gestures and learners. Not only do task demands vary (e.g., procedural vs. declarative memory/learning), there are also all kinds of gestures (e.g., deictic gestures, such as pointing, representational gestures, beat gestures, emblems), manners of gesture use (observed or self-performed), and learner characteristics (e.g., age, proficiency in certain areas, intelligence, experience) that might play a role in the effectiveness of gesturing for learning. Connecting the right type of gesture to the right task for the right type of learners is a complex puzzle. This dissertation tried to find some (small) pieces of that puzzle by studying the effects of deictic gestures on different types of memory and learning tasks in different age groups.

Despite the fact that deictic gestures did not have a positive effect on learning in the studies described in Part 1, pointing did seem to help guide learners' visual attention toward task relevant areas on crucial time points during the instruction. This makes deictic gestures a promising cueing tool in dynamic visualizations (such as video or animations) that show information in a transient manner, meaning that it should be attended to timely or is no longer available for processing.

In Part 2, the contradictive findings between the studies reported in Chapters 4 and 5 concerning the effect of pointing toward pictures on spatial source memory, were explained by a 'selectivity' account; if the task requires a selection process for a subset of the stimuli, pointing facilitates further processing and memory for these pointed items compared with the items that are only observed. In daily life, selectivity is part of almost all our behavior; every action is selected from a variety of other possible actions that need to be inhibited. Therefore, the results of the study reported in Chapter 4 might be more informative with regard to practical implications regarding the use of pointing gestures than those in Chapter 5,

The study described in Chapter 6 showed that a multimodal compared with a unimodal encoding strategy improved visuospatial working memory performance in both young and older adults (Experiment 1) and that adding visual cues to the multimodal but not the unimodal encoding strategy improved the performance of older adults on the visuospatial working memory task up to the level of young adults. Furthermore, a multimodal encoding strategy together with predictive visual cues can ameliorate temporal decay in working memory in both young and older adults. These findings are especially interesting from an aging perspective, because it suggests that gestures and visual cues can be used as tools to compensate for age-related declines in visuospatial working memory performance (at least, in the present paradigm).

An implication of the results presented in Part 2 is that self-produced gestures can enhance spatial source memory and visuospatial working memory. It is possible that via the attentional bias toward objects we tend to act upon and the fact that pointing forces our attention toward a certain location, this type of body-based involvement in memory encoding can be used in learning different kinds of tasks that target visuospatial skills.

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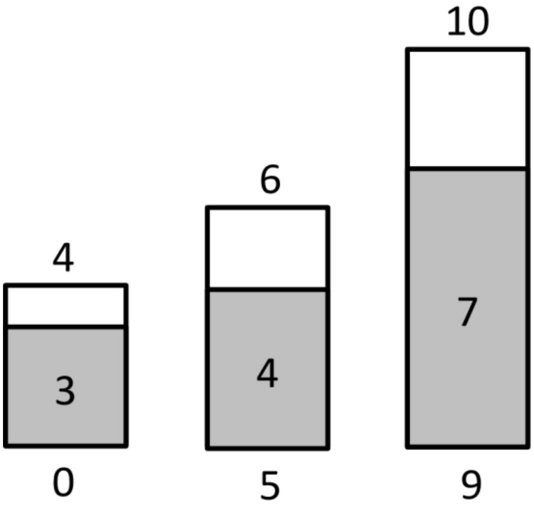
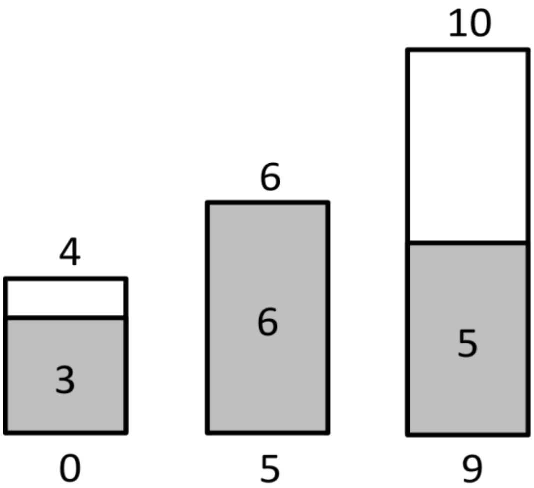
Appendices

Appendix 1

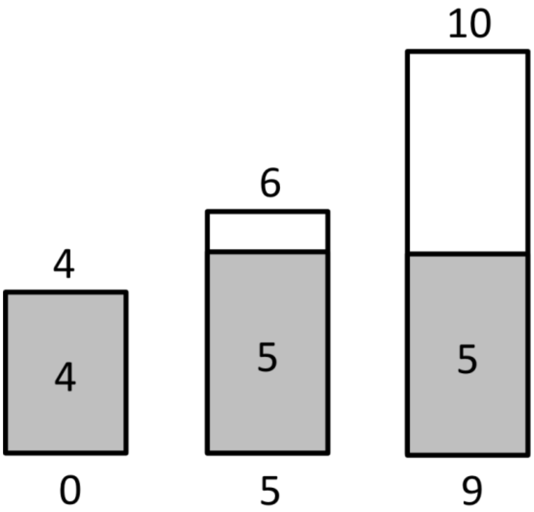
Verbal script of the video



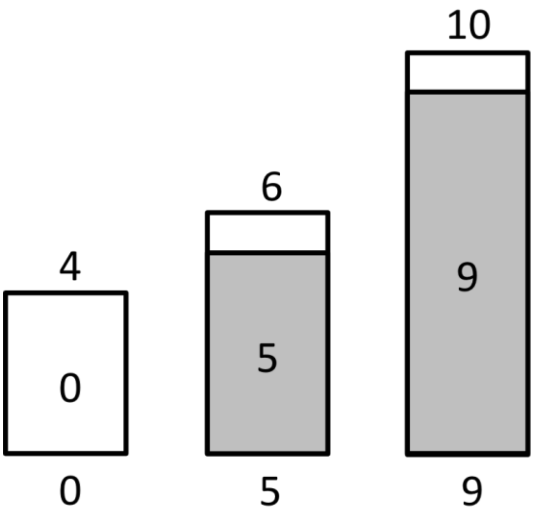
*"The next problem can be solved in 3 steps. The correct solution can be found if you focus on the goal amount of the large jug. You can see the solution in the next formula; the current quantity – the quantity that can be added to the medium jug, + the maximum quantity of the small jug, or **7 - 2 + 4 = 9**.*
The first step is to pour water from the large jug to the medium jug. The medium jug will reach a quantity of 4 + 2 = 6. The large jug will reach a quantity of 7 - 2 = 5.
After the first step, the jugs look like this". Next slide appears.



*"The second step is to pour water from the medium jug to the small jug. The medium jug will reach a quantity of **6 - 1 = 5, which is equal to its goal amount**. The small jug will reach a quantity of 3 + 1 = 4. After the second step, the jugs look like this."* Next slide appears.



“The final step is to pour water from the small jug to the large jug. The small jug will reach a quantity of ***4 - 4 = 0, which is equal to its goal amount****. The large jug will reach a quantity of 5 + 4 = 9, which is equal to its goal amount. After the final step, the jugs look like this.* Next slide appears.



“The problem is now solved.” End of video.

Appendix 2

Pilot test Chapter 4

Before experimental testing, the paradigm described above was pilot tested in 24 young adults (16 women, six men, M_{age} = 22.1 years, *SD* = 3.8 years, age range 18–32 years), enrolled at a Dutch university. They participated for course credits or voluntarily. A within-subjects design, with encoding condition (pointing vs. naming) as within-subjects factor was used.

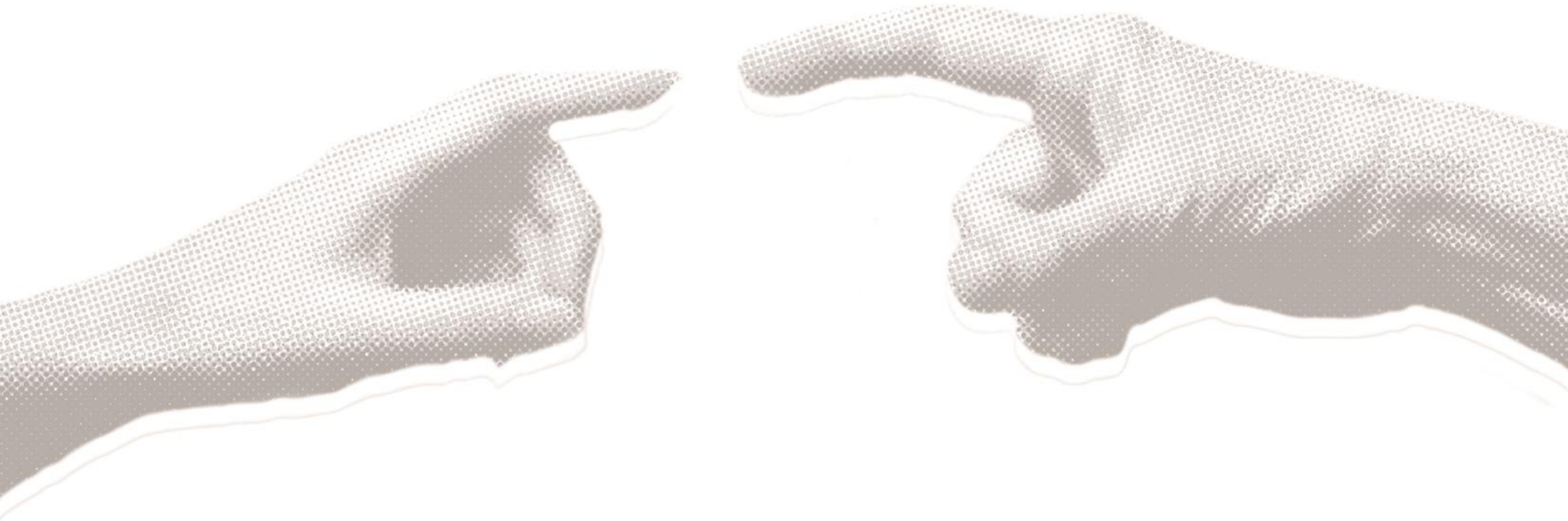
Response accuracy for the pointed and named items during the encoding stage was high (pointing, *M* = 98.44%, *SD* = 2.40; naming, *M* = 99.57%, *SD* = 1.37). Means and standard deviations of item and source memory scores can be found in Table 1. A repeated measures ANOVA with encoding condition as within-subjects factor, showed no effect of encoding condition on item memory performance, $F(1, 23) = 0.68$, $MSE = 153.22$, $p = .417$, $\eta_p^2 = .03$, but encoding condition did have a significant effect on source memory performance, $F(1, 23) = 13.52$, $MSE = 56.24$, $p = .001$, $\eta_p^2 = .37$, indicating that pointing improved source memory more than naming). Table 1 shows all means and standard deviations for the percentage correct on item and source memory performance.

Table 1.
Means and Standard Deviations of Young Adults' Item and Source Memory Accuracy in the pilot test for Experiment 1 of ***Chapter 4***

Type of Memory	Item		Source	
Condition	*M*	*SD*	*M*	*SD*
Pointing (%)	67.01	15.87	61.84	16.72
Naming (%)	64.06	11.74	53.88	14.60

Note. *N* = 24.

Samenvatting (Summary in Dutch)



In de studies in deze dissertatie werd onderzocht of het observeren of maken van deiktische gebaren het geheugen en het leren van kinderen, jongvolwassenen en ouderen zou kunnen versterken. Deiktische gebaren betreffen het aanwijzen van een object of het met de vinger overtrekken van een object zelf of zijn bewegingstraject. Met betrekking tot het geheugen, werd onderzocht of deiktische gebaren de prestaties op taken die het werkgeheugen, cognitieve controle en het contextuele geheugen meten, zouden kunnen verbeteren. Deze cognitieve functies zijn bij kinderen nog in ontwikkeling en zijn bij ouderen aan het afnemen. Daarom werd tevens onderzocht of de verwachtte effecten van gebaren groter zouden zijn voor kinderen en voor ouderen dan voor jongvolwassenen.

In de studies in het eerste deel van deze dissertatie werd het effect van observeren van deiktische gebaren op het leren van kinderen, jongvolwassenen en ouderen (Hoofdstuk 2), alsmede het effect op de visuele aandacht van jongvolwassenen (Hoofdstuk 3), onderzocht. De proefpersonen observeerden gebaren gemaakt door een docent tijdens een video-instructie van een probleemoplos-taak. In het tweede deel werden effecten van het maken van deiktische gebaren tijdens het onthouden (memoriseren) van informatie (inhoud en locatie van plaatjes) onderzocht. Hierbij werd zowel het contextuele geheugen voor ruimtelijke informatie (de locaties van de plaatjes) bij jongvolwassenen en ouderen (Hoofdstuk 4) en kinderen en jongvolwassenen (Hoofdstuk 5) gemeten, als het visuospatiële werkgeheugen in jongvolwassenen en ouderen (Hoofdstuk 6).

Deel 1

In de studies in Deel 1 werd onderzocht of het observeren van deiktische gebaren van een docent die een taak uitlegt, de aandacht en het leerproces van leerlingen positief kan beïnvloeden. In **Hoofdstuk 2** werd in drie experimenten onderzocht of het leren van een nieuwe probleemoplos-taak aan de hand van een video-voorbeeld verbeterde wanneer de docent naar relevante delen van de taak wees, bij kinderen (Experiment 1), jongvolwassenen (Experiment 2) en ouderen (Experiment 3). Het video-voorbeeld was gebaseerd op een typische moderne leersituatie waarin de docent naast een whiteboard stond waarop de taak werd weergegeven. Er werd een computergestuurde versie van Luchins' (1952) 'Water jug task' (Schmid, Wirth, & Polkehn, 2003) gebruikt, waarin de hoeveelheid water in drie verschillende bekers op een bepaalde manier herverdeeld moest worden. In het video-voorbeeld zagen de deelnemers een vrouwelijke docent die de taak verbaal uitlegde en afhankelijk van de experimentele conditie; (i) hoofdbewegingen naar het scherm maakte (conditie "geen expliciete aanwijzingen"), (ii) hoofdbewegingen maakte terwijl een pijl het gebied aanwees waar zij over sprak (conditie "pijl aanwijzingen"), of (iii) hoofdbewegingen maakte en de gebieden waarover zij sprak met de wijsvinger aanwees en aanduidde van welke naar welke beker water moest worden overgeschonken (conditie "aanwijsgebaren").

Verondersteld werd dat de conditie met aanwijsgebaren tot beter en efficiënter leren zou leiden dan de andere twee condities. Omdat gebaren vooral lijken te helpen bij het leren van complexe taken, wanneer cognitieve belasting hoog is (Chu & Kita, 2011; Goldin-Meadow, Nusbaum, Kelly, & Wagner, 2001; McNeill, Alibali, & Evans, 2000), werden twee niveaus van taakcomplexiteit (hoger en lager) gebruikt. Omdat bij kinderen en ouderen sommige cognitieve functies die belangrijk zijn voor het leren van nieuwe probleemoplos-taken, nog niet of niet meer optimaal functioneren, zoals het werkgeheugen en cognitieve controle (Crone, Wendelken, Donohue, Van Lijenhorst, & Bunge, 2006; Vecchi, Richardson, & Cavallini, 2005), werd verwacht dat de taken op beide complexiteitsniveaus moeilijker zouden zijn voor deze groepen dan voor jongvolwassenen. Daarom werd er naast een effect van taakcomplexiteit binnen groepen, ook een effect tussen de groepen verwacht, namelijk dat jongvolwassenen beter zouden presteren op de taak dan kinderen en ouderen. Omdat verwacht werd dat de taakcomplexiteit relatief hoger zou zijn voor kinderen en ouderen dan voor jongvolwassenen, werd ook verwacht dat het mogelijke leervoordeel ook hoger zou zijn voor deze groepen dan voor jongvolwassenen.

Naar verwachting presteerden alle groepen beter op de simpele problemen dan de complexe problemen en gaven ze aan dat de simpele problemen minder moeite kostten dan de complexe problemen. De jongvolwassenen presteerden beter dan de ouderen, wat een typisch leeftijdseffect is. Daarnaast werd gevonden dat ook de kinderen beter presteerden dan de ouderen. Deze bevindingen benadrukken dat het vooral voor ouderen belangrijk is dat er wordt gezocht naar een geschikte vorm van instructie om leeftijdsgerelateerde beperkingen te compenseren en leren te verbeteren. Er werd echter maar weinig bewijs gevonden voor de positieve effecten van gebaren in instructie. Gebaren van de docent leidden tot een voordeel voor ouderen in termen van de tijd die ze nodig hadden voor het oplossen van isomorfe problemen: ouderen in de conditie met gebaren waren sneller in het oplossen van problemen die dezelfde oplossingsstructuur hadden als het probleem in het video-voorbeeld dan ouderen in de conditie zonder expliciete aanwijzingen tijdens de video-instructie. Er werden geen andere positieve effecten van het observeren van de gebaren van de docent gevonden.

In de studie beschreven in **Hoofdstuk 3** werd met eye-tracking onderzocht of gebaren van een vrouwelijke docent in een video-voorbeeld studenten zou helpen om hun aandacht tijdig te richten op de taakaspecten waar zij naar verwees. Deze studie maakte gebruik van dezelfde video-voorbeelden als de studie in Hoofdstuk 2, maar de condities waren iets anders: (i) het model keek alleen recht in de camera (conditie “geen aanwijzingen”), (ii) het model draaide haar hoofd zo nu en dan naar de taakweergave op het whiteboard als zij over een deel van de taak sprak (conditie “kijken”) of, (iii) het model maakte deze hoofdbewegingen en wees het deel van de taak waarover ze sprak aan met haar wijsvinger en volgde met haar wijsvinger de stap van welke naar welke beker water moest worden overgeschonken (conditie “kijken + gebaren”). Tijdens het leren werden de oogbewegingen van studenten opgenomen (met eye-tracking apparatuur). Omdat bekend is dat menselijke gezichten en (deiktische) gebaren automatisch de aandacht trekken, werd verondersteld dat de deelnemers in de “kijken” en vooral in de “kijken + gebaren” conditie, beter hun aandacht zouden verleggen van de docent naar de delen van de taak (op het scherm) waar zij over sprak. Er werd een duidelijke trend gevonden in overeenkomst met deze verwachting: Studenten in alle condities keken meer naar de docent dan naar de delen van de taak waar zij over sprak[1]. In de “kijken“ conditie werd echter iets meer naar de delen van de taak gekeken waar zij over sprak, en in de “kijken + gebaren” conditie was dit nog sterker het geval. Kortom, het kijken en vooral het kijken en gebaren, gaf studenten aanwijzingen die hielpen om hun aandacht te sturen naar de taakgebieden waar de docent over sprak. Hoewel er geen leereffecten werden gevonden (die ook niet echt te verwachten waren gegeven de kleine groepsgrootte), suggereren de bevindingen dat gebaren een effectief middel zijn om de aandacht van studenten tijdens het leren van video-voorbeelden waarin de docent of instructeur zichtbaar is, op het juiste moment naar de juiste plaats te sturen.

Dat ouderen in de “gebaren conditie” sneller isomorfe problemen oplosten (Hoofdstuk 2), suggereert dat gebaren in instructies kunnen compenseren voor tragere prestaties in cognitieve taken; mogelijk omdat zij de aandacht op het juiste moment naar de juiste plaats leiden (Hoofdstuk 3). Toekomstig onderzoek zou kunnen nagaan of dit ook betekent dat ouderen in een bepaald tijdsbestek meer problemen zouden kunnen oplossen na het zien van gebaren in video-instructies. Omdat het huidige onderzoek met slechts één bepaalde taak werd uitgevoerd, is het van belang verder te onderzoeken onder welke omstandigheden gebaren in video-instructies en andersoortige leermaterialen het leren kunnen verbeteren. In het bijzonder voor populaties die mogelijk moeite ondervinden met bestaande leeromgevingen vanwege een niet optimaal functionerend werkgeheugen, zoals ouderen, is dit relevant; zij maken namelijk wel steeds meer gebruik van online video’s (Chen & Persson, 2002).

Deel 2

In de studies in Deel 2 werd onderzocht of het zelf aanwijzen van plaatjes het contextuele geheugen voor de inhoud en de locatie van de plaatjes (Hoofdstukken 4 en 5) en visuospatieel werkgeheugen voor een serie locaties (Hoofdstuk 6) kan verbeteren. Gezond ouder worden gaat gepaard met een afname in werkgeheugen (Salthouse & Babcock, 1991), contextueel geheugen (Old & Naveh-Benjamin, 2008), cognitieve snelheid (Salthouse, 1996, 2000), en

[1] NB: dit betekent niet dat ze een groter deel van de tijd keken naar de docent dan naar de taak in het algemeen; ze keken minder naar het deel van de taak dat relevant was op het moment dat de docent erover sprak.

controle over interferentie (e.g., Houx, Jolles, & Vreeling, 1993; Stolzfus, Hasher, Zacks, Ulivi, & Goldstein, 1993). Daarom is het belangrijk voor het functioneren van ouderen om strategieën te vinden die kunnen compenseren voor deze leeftijdsgerelateerde afname in cognitieve functies.

In de twee experimenten in **Hoofdstuk 4** werd onderzocht of het aanwijzen van locaties van plaatjes tijdens het memoriseren van de plaatjes, het contextuele geheugen voor de locaties van de plaatjes zou verbeteren vergeleken met het verbaal benoemen van de locaties of het alleen bekijken van de plaatjes. Omdat aanwijsgebaren een visuospatieel karakter hebben (ze duiden of refereren naar objecten of locaties in de ruimte), werd verondersteld dat aanwijzen een geschikte strategie zou zijn om het memoriseren van ruimtelijke contextuele informatie te verbeteren, die zou moeten resulteren in het beter onthouden van de locaties van de plaatjes. Overeenkomstig met de verwachting, werd, bij zowel jongvolwassenen als ouderen, gevonden dat aanwijzen tijdens het memoriseren van de plaatjes en locaties tot een beter contextueel geheugen voor de locaties van de plaatjes leidde, dan het benoemen van de locaties of het alleen kijken naar de plaatjes. Ook volgens verwachting, waren ouderen net zo goed als jongvolwassenen in het herkennen van de plaatjes (afzonderlijk van de locaties), maar waren ze slechter dan jongvolwassenen in het herinneren van de locaties van de plaatjes. Het aanwijzen compenseerde niet voor de leeftijdsgerelateerde afname in contextueel geheugen, omdat jongvolwassenen en ouderen evenveel voordeel hadden van aanwijzen ten opzichte van benoemen en kijken alleen.

In de twee experimenten in **Hoofdstuk 5** werd onderzocht of het aanwijzen van locaties van plaatjes het contextuele geheugen voor ruimtelijke informatie (de locaties van plaatjes) van kinderen en jongvolwassenen kan verbeteren ten opzichte van alleen kijken. In deze studie werd nog een factor toegevoegd, namelijk de congruentie tussen plaatje en locatie. Een locatie was congruent wanneer deze overeenkwam met de meest voorkomende eerdere ervaring met het object of beeld wat er op het plaatje te zien was en incongruent wanneer de locatie niet overeenkomstig de ervaring was. De locatie van een plaatje van een wolk zou dus congruent zijn wanneer het plaatje bovenin het computerscherm werd gepresenteerd en incongruent indien het plaatje onderin het scherm werd gepresenteerd. Hoewel het geheugen voor inhoud (feiten zonder context) en context (feiten in een bepaalde context) nog in ontwikkeling is bij kinderen, maakt het contextuele geheugen de grootste ontwikkeling door tussen kindertijd en jongvolwassenheid (Cycowicz, Friedman, Snodgrass, & Duff, 2001). Verondersteld werd dat aanwijzen van plaatjes tijdens het memoriseren beter zou zijn voor het contextuele geheugen voor de locaties van die plaatjes, dan er alleen naar kijken, voor zowel kinderen (Experiment 1) als jongvolwassenen (Experiment 2). Ook werd verwacht dat dit effect groter zou zijn voor kinderen omdat hun geheugenfuncties nog in ontwikkeling zijn en er daarom mogelijk meer winst te behalen was voor deze groep. Ook werd verwacht op basis van theorieën over 'belichaamde cognitie' (embodied cognition; e.g., Barsalou, 2008), dat het contextuele geheugen voor congruente locaties van plaatjes beter zou zijn dan voor incongruente locaties.

Volgens verwachting lieten de resultaten van de studie in Hoofdstuk 5 een duidelijk congruentie effect zien voor de prestatie op de contextuele geheugentest, bij zowel kinderen als jongvolwassenen: proefpersonen herinnerden zich meer locaties van plaatjes die op congruente locaties waren gepresenteerd dan op incongruente. Echter, in tegenstelling tot de bevindingen van de studie in Hoofdstuk 4, waaruit een voordeel van aanwijzen op het contextuele geheugen van jongvolwassenen en ouderen bleek, lieten de experimenten in Hoofdstuk 5 geen positief effect van aanwijzen op het contextuele geheugen zien. De jongvolwassenen die plaatjes aangewezen hadden, waren weliswaar sneller in het herkennen van de plaatjes dan jongvolwassenen die niet aangewezen hadden, maar ze waren niet accurater in het herkennen van de plaatjes of de locatie.

De tegenstrijdige resultaten van de experimenten in Hoofdstuk 4 waaruit een positief effect van aanwijzen op het contextuele geheugen voor locaties van plaatjes bleek en de experimenten in Hoofdstuk 5 waarin dit niet het geval was, kunnen mogelijk verklaard worden door een verschil in de experimentele opzet tussen de studies. In de studie in Hoofdstuk 4 werd namelijk een binnen-proefpersonen opzet gebruikt en in de studie in Hoofdstuk 5 een tussen-proefpersonen opzet. Dit betekent dat proefpersonen in de studie in Hoofdstuk 4, selectief naar sommige plaatjes moesten wijzen terwijl ze naar andere plaatjes alleen hoefden te kijken (of de locatie benoemen), terwijl ze in de studie beschreven in Hoofdstuk 5, naar *alle* plaatjes moesten wijzen of naar *alle* plaatjes moesten kijken (de helft van de proefpersonen wees naar de locaties en de andere helft keek naar of benoemde de locaties alleen). Het verschil in resultaten valt mogelijk dan ook te verklaren vanuit de selectie-voor-actie hypothese (Allport, 1989) die stelt dat selectie voor actie een aandachtsbias creëert voor objecten die actie vereisen. De selectieve aard van de leerfase in een binnen-proefpersonen opzet zoals in de studie in Hoofdstuk 4, zorgt ervoor dat de inhoud van de plaatjes minstens op een semantisch (betekenis) niveau wordt verwerkt; de proefpersonen moesten een plaatje aanwijzen of niet, afhankelijk van of er een natuurlijk of kunstmatig object te zien was. De tussen-proefpersonenopzet gebruikt in de studie in Hoofdstuk 5, vereist niet dat de inhoud van de plaatjes op betekenisniveau wordt verwerkt, waardoor het aanwijzen niet wezenlijk bijdraagt aan het versterken van de associatie tussen de inhoud en de locatie van het plaatje.

In **Hoofdstuk 6** werd in twee experimenten onderzocht of aanwijzen het visuospatieel werkgeheugen van jongvolwassenen en ouderen zou verbeteren. Voor deze studie werd een visuospatiële werkgeheugentaak gebruikt, ontwikkeld door Chum, Bekkering, Dodd, en Pratt (2007). In deze taak moesten proefpersonen de locaties van een reeks simpele figuren onthouden. In de studie van Chum et al. (2007) kregen de deelnemers korte opgaven die bestonden uit het bekijken van twee reeksen figuren (een reeks vierkanten en een reeks cirkels, variërend van drie tot vijf figuren per reeks). De figuren binnen elke reeks werden opeenvolgend getoond op verschillende locaties op het scherm. De helft van de deelnemers moest de cirkels aanwijzen en de andere helft van deelnemers moest de vierkanten aanwijzen. Na iedere opgave werd het visuospatiële werkgeheugen voor een van de reeksen (locaties van de cirkels of de vierkanten) getest. Dit betekent dat de locaties van beide reeksen actief in het werkgeheugen gehouden moesten worden tot de testfase, maar dat er maar een van de reeksen relevant was voor de test. Chum et al. vonden dat aanwijzen tot betere prestaties op de visuospatiële werkgeheugentaak leidde dan kijken alleen. Ook vonden ze een effect van recentheid: deelnemers presteerden beter wanneer de afstand in tijd tussen leer- en testfase het kleinst was; dus de prestaties waren beter wanneer ze getest werden op de laatst getoonde reeks figuren dan wanneer ze getest werden op de eerst getoonde reeks. Verder vonden Chum et al. dat het positieve effect van aanwijzen op het visuospatieel werkgeheugen afnam naarmate de reeksen figuren langer werden en dat dit effect zelfs was verdwenen bij de langste reeksen (vijf cirkels en vijf vierkanten).

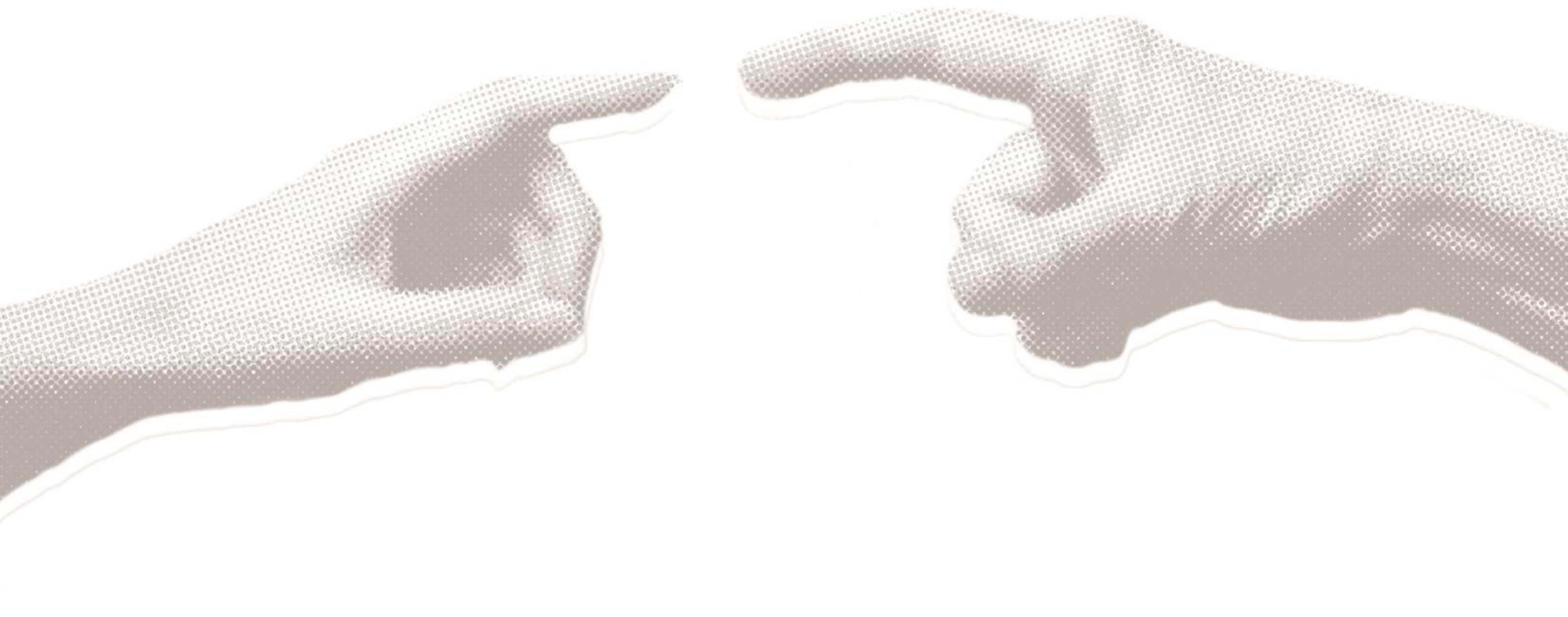
Experiment 1 was erop gericht om de bevindingen van Chum et al. (2007) voor wat betreft de korte reeksen te repliceren met jongvolwassenen en te kijken of dezelfde effecten ook bij ouderen gevonden zouden worden. Volgens verwachting werd in Experiment 1 het voordeel van aanwijzen en het effect van recentheid gerepliceerd in zowel jongvolwassenen als ouderen. De jongvolwassenen presteerden beter dan de ouderen, waaruit kon worden afgeleid dat aanwijzen niet compenseerde voor leeftijdsgerelateerde afname in het visuospatiële werkgeheugen.

In Experiment 2 werd onderzocht of het gebruik van signalen die aangaven welke reeks relevant was voor de test, het effect van aanwijzen zou kunnen versterken. Tevens stelde dit ons in staat om na te gaan of het effect van recentheid puur veroorzaakt werd door de tijd tussen leer- en testfase (zoals Chum et al., 2007, veronderstelden) of ook door het feit dat wanneer de eerste reeks getest wordt, niet alleen de tijd tot de test langer is maar er ook interferentie van de irrelevante (tweede) reeks is. Verwacht werd dat het aanbieden van visuele signalen het effect van aanwijzen zou versterken (vooral in ouderen) en het effect van recentheid zou verkleinen. En inderdaad, het aanbieden van signalen samen met aanwijzen verbeterden de prestaties van ouderen tot op het niveau van de jongvolwassenen. Verder werd gevonden dat signalen aangeboden *voorafgaand* aan de leerfase samen met aanwijzen de prestaties op de opgaven waarin de eerste reeks werd getest, verbeterden, (waarbij de tijdspanne tussen leer- en testfase dus het grootst was), bij zowel jongvolwassenen als ouderen. Dit suggereert ook dat niet alleen de tijd tussen leer- en testfase de oorzaak is van het effect van recentheid, maar ook de interferentie van de irrelevante reeks een rol speelt (wanneer men immers weet dat de tweede reeks niet getest wordt, zal hieraan geen/minder aandacht worden besteed). Signalen aangeboden *na* de leerfase in combinatie met aanwijzen, verbeterden de prestaties op de opgaven waarin de tweede reeks werd getest. Dit komt overeen met Experiment 1 waarin ook werd gevonden dat multimodaal memoriseren van de locaties van de figuren de prestatie van jongvolwassenen en ouderen op de taak verbeterde wanneer de tweede reeks werd getest.

Een aannemelijke verklaring voor de bevinding dat de prestatie van ouderen verbeterde tot op het niveau van de jongvolwassenen door de combinatie van signalen en aanwijzen, is dat het weten welke reeks relevant is, de werkgeheugenbelasting verlaagt, waardoor het effect van aanwijzen werd versterkt bij ouderen (vgl. de bevinding van Chum et al., 2007, die ook lieten zien dat het effect van aanwijzen toenam bij lagere werkgeheugenbelasting). Dit is een erg belangrijke bevinding omdat dit suggereert dat aanwijzen in combinatie met visuele signalen kan worden gebruikt om voor leeftijdsgerelateerde afname in visuospatieel werkgeheugen te compenseren (tenminste, in het gebruikte binnen-proefpersonen design, waarin er net als in Hoofdstuk 4, sprake is van selectie –sommige figuren werden aangewezen, andere niet).

In conclusie, de studies in Deel 2 lieten zien dat het aanwijzen van de locaties van plaatjes leidde tot een beter contextueel geheugen voor ruimtelijke informatie (plaatje-locatie associaties) en visuospatieel werkgeheugen voor die locaties dan alleen kijken naar plaatjes, wanneer de deelnemers selectief een deel van de plaatjes moesten aanwijzen. Waarschijnlijk zorgt de aandachtsbias voor objecten die (de intentie tot) actie vereisen, plus het feit dat aanwijzen de aandacht dwingt naar een bepaalde locatie, ervoor dat het gebruik van het lichaam helpt bij het onthouden van locaties. Dit gegeven kan worden gebruikt voor het verbeteren van het contextueel geheugen en visuospatieel werkgeheugen in zowel jongvolwassenen als ouderen, wat met name voor die laatste groep zeer relevant is vanwege de leeftijdsgerelateerde afname van deze geheugenfuncties.

Dankwoord



De periode van mijn promotietraject is omgevlogen. Aan de ene kant ben ik blij en trots, maar aan de andere kant vind ik het jammer dat hiermee ook een einde is gekomen aan deze leerzame en leuke tijd. Tijdens deze periode zijn er veel lieve mensen geweest die mij begeleiding, hulp, steun en vriendschap hebben geboden. Graag wil ik hen bedanken daarvoor.

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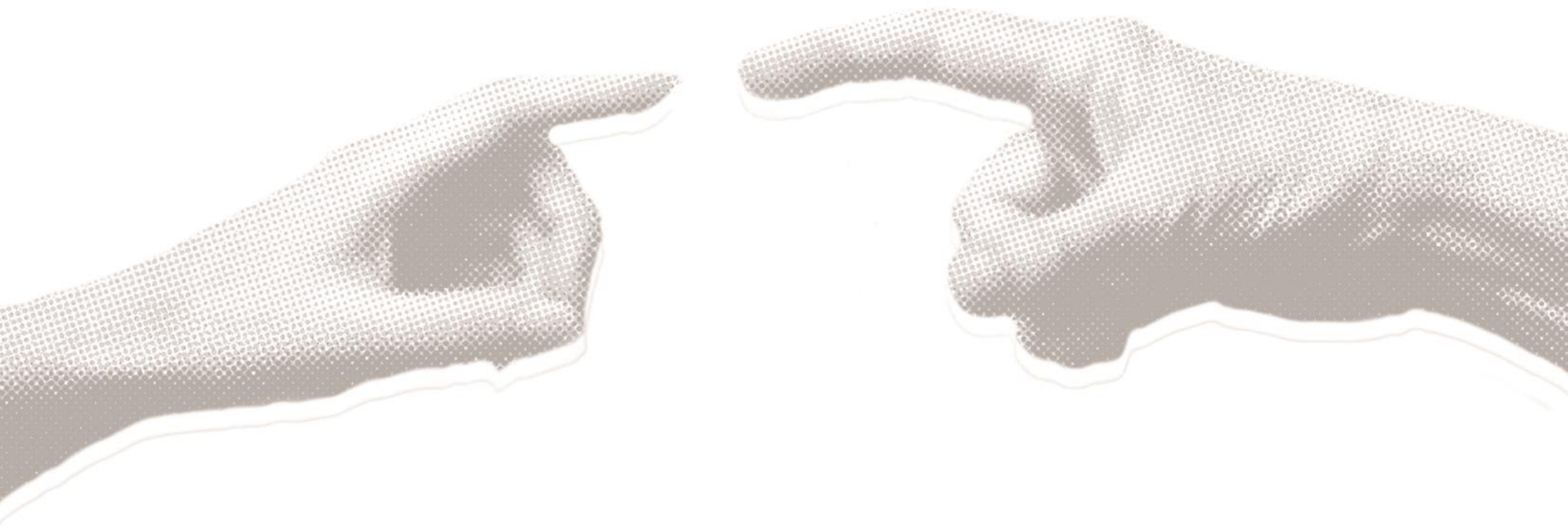
Publications



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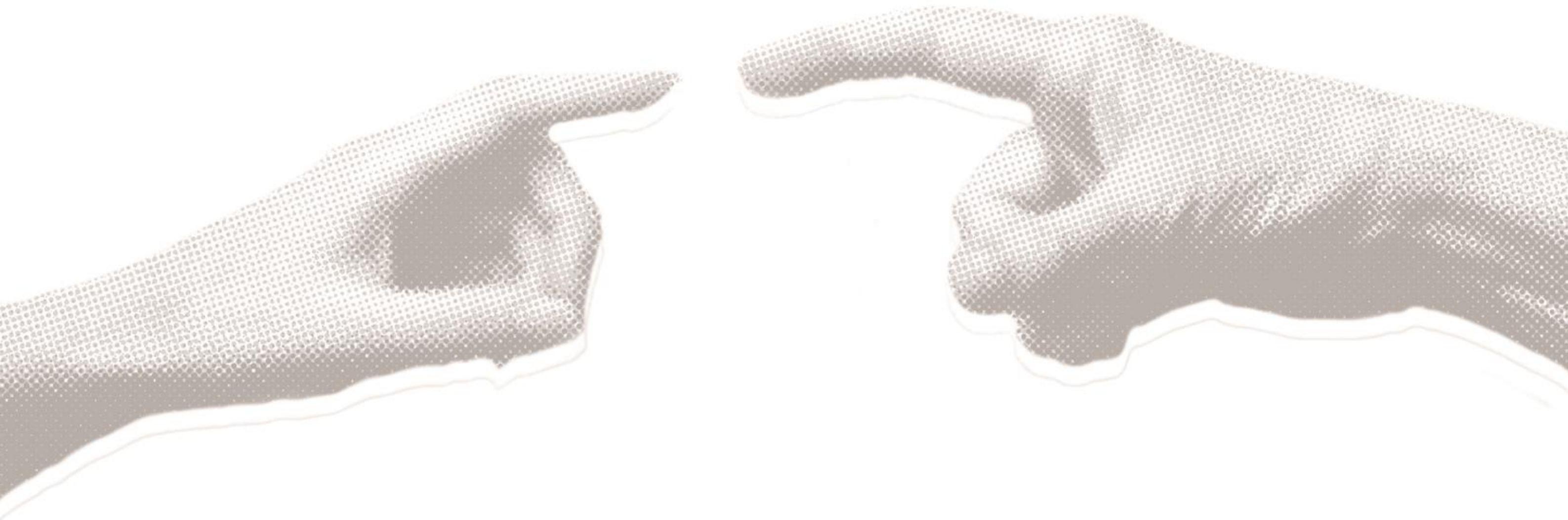
Curriculum Vitae



Curriculum Vitae

Kim Ouwehand was born on June 3rd, 1981 in Seoul, South Korea. She completed her secondary education in 1998 at Andreas College in Katwijk, the Netherlands. After highschool she studied at the Amsterdam Fasion Institute at which she obtained her propadeutic diploma in 1999. In 2005, she obtained her Bachelor's degree in Arts Therapy at Hogeschool Leiden, in 2008 her Bachelor's degree in Psychology and in 2010 her (Research) Master's degree in Psychology (Cognitive Neuroscience track). During her studies at Leiden University, Kim joined the Honours lectures and the Honours bachelor programme. Besides her studies Kim worked in elderly homes, psychiatric institutions and child day care centers and as a research assistant at Leiden University. In addition she also worked as a volunteer for the Red Cross and in a local community youth centre. In September 2010, Kim started as a PhD candidate at the Erasmus University Rotterdam, studying the effects of observing and producing deictic gestures on memory and learning in different age groups, resulting in this dissertation. During her PhD Kim was a PhD representative in the ICO educational committee from 2013 to 2014.

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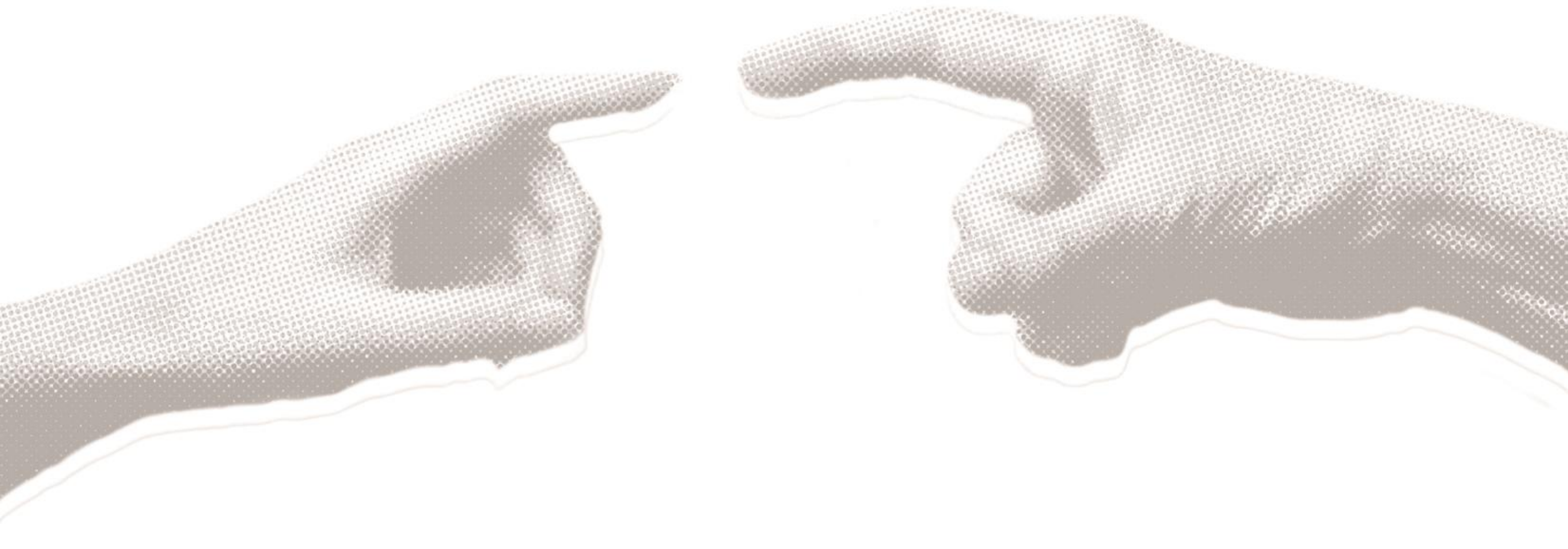

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