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Effects of simultaneously observing and making gestures while studying grammar animations on cognitive load and learning

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ABSTRACT

This study examined whether simultaneously observing and making gestures while studying animations would lighten cognitive load and facilitate the acquisition of grammatical rules. In contrast to our hypothesis, results showed that children in the gesturing condition performed worse on the posttest than children in the non-gesturing, control condition. A more detailed analysis of the data revealed an expertise reversal effect, indicating that this negative effect on posttest performance materialized for children with lower levels of general language skills, but not for children with higher levels of general language skills. The finding that for children with lower language ability, cognitive load did not decrease as they saw more animations provided additional support for this expertise reversal effect. These findings suggest that the combination of observing and making gestures may have imposed extraneous cognitive load on the lower ability children, which they could not accommodate together with the relatively high intrinsic load imposed by the learning task.

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1. Introduction

Although instructional animations are widely used in education, they are not always effective for learning, because the information presented is transient (Ayres & Paas, 2007). Information appears and then disappears and one is often required to keep the disappeared information in mind in order to comprehend the next piece of information. This is a highly demanding task for working memory, which is limited in capacity (e.g., Cowan, 2001; Miller, 1956). According to Cognitive Load Theory (CLT; Sweller, 1988; Sweller, Van Merriënboer, & Paas, 1998) this causes a high cognitive load. CLT describes three types of cognitive load that play a role in learning (Paas, Tuovinen, Tabbers, & Van Gerven, 2003; Sweller et al., 1998). Intrinsic load is determined by the difficulty of the content of what is to be learned. The higher the number of interacting information elements, the more difficult the material is for the learner and the higher the intrinsic load (Sweller, 1994). Note that this also depends on learner expertise – with increasing expertise more information elements are combined into schemata, which reduces the intrinsic load of a task. Extraneous load is caused by the design of instruction and does not contribute to learning. Germane load on the other hand is also caused by the design of instruction, but is beneficial for learning. Thus, the last two types of cognitive load can be altered by instructional designers, depending on the instructional format used. With instructional animations, for instance, it has been found that counteracting negative effects of transience by means of cueing (De Koning, Tabbers, Rikers, & Paas, 2009, 2010a) or segmenting (Spanjers, Van Gog, Wouters, & Van Merriënboer, 2012) makes animations more effective for learning.

Regarding the negative effect of transience on learning from instructional animations, there is an exception: When they demonstrate human movement tasks, dynamic visualizations such as videos or animations are often effective (Höffler & Leutner, 2007; Van Gog, Paas, Marcus, Ayres, & Sweller, 2009). It has been proposed (Van Gog et al., 2009) that this might be due to the mirror neuron system that is activated when one sees someone else perform an action – this is assumed to form the basis of the human capability to learn through imitation (Rizzolatti & Craighero, 2004). As human neurons respond to observing actions as a basis for learning, it might be that transience poses less of a problem in terms of working memory load, and procedures are acquired more easily when human movement tasks are depicted in animations.

In line with this notion of the mirror neuron system, embodied cognition theories also put forth an involvement of the motor system in learning. Embodied accounts of cognition postulate that cognitive processes are grounded in perception and bodily actions (Barsalou, 1999; Wilson, 2002). Thus, cognitive representations of symbols like numbers and letters are ultimately based on sensorimotor codes within a generalized system that was originally devel-

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oped to control an organism's motor behavior and perceive the world around it. In line with this view, memory for action phrases (e.g., 'Lift the pen.') has been shown to be better when participants had performed the action themselves (Engelkamp & Zimmer, 1997). Moreover, the semantics of such action phrases influenced behavior in another study, with faster reading times when meaning and motion were congruent (e.g., 'He started the car'; Zwaan, Taylor, & De Boer, 2010).

These embodied cognition studies suggest a link between semantics and the motor system, and it has been proposed that animations can be improved by activating the motor system by showing gestures (to which mirror neurons would respond) or asking learners to make gestures, even for non-human movement tasks (as in mathematical procedures or grammar; e.g., De Koning & Tabbers, 2011). Importantly, making gestures has been shown to lower cognitive load during math problem solving (Goldin-Meadow, Nusbaum, Kelly, & Wagner, 2001) and to foster learning: When instructed to gesture while explaining math problems, children added new problem-solving strategies to their repertoire and remembered more from a subsequent lesson from the teacher (Broaders, Cook, Mitchell, & Goldin-Meadow, 2007) and this beneficial effect was retained after four weeks (Cook, Mitchell, & Goldin-Meadow, 2008). Observation of gestures was also found to be effective for children's learning (Ping & Goldin-Meadow, 2008). Children had higher learning benefits when they saw guiding gestures (indicating sizes of objects) while learning Piagetian conservation tasks than when they did not observe gestures.

The present study focuses on the role of gestures in learning first-language grammar rules from animations, more specifically the grammatical rules for transforming an active sentence into a passive sentence. Considering language acquisition, research on the effects of gestures has mainly focused on second language learning and on concrete topics such as word learning. For instance, a study on word learning found that French children who were instructed to imitate gestures during word learning produced more English words on a test than children who were not instructed to gesture (Tellier, 2008). However, little research has been done considering the use of gestures in first language acquisition and learning more abstract concepts, such as grammar rules. Thus, it is unknown whether effects of gestures extend to learning abstract concepts in one's native language. Although, both observing gestures and making gestures have been shown to positively affect learning, the effects of the combined use of both techniques are unknown. We would predict learning benefits of both observing and making gestures through activation of the motor system and lightening of cognitive load. It is plausible that the effects would add up to an even higher learning benefit than of each of them separately. However, we have not found any literature examining this combined effect of simultaneously observing and making gestures. Moreover, very little research has been conducted on learning such abstract content as grammar rules from animations. Most research on instructional animations has focused on biological (e.g., how the heart works; De Koning, Tabbers, Rikers, & Paas, 2010b), natural (e.g., how lightning develops; Mayer & Moreno, 1998), or mechanical processes (e.g., how a piano works; Boucheix & Lowe, 2010), or on human-movement (e.g., origami; Wong et al., 2009) and problem-solving procedures (e.g., probability calculation; Spanjers et al., 2012). To the best of our knowledge, there are some studies on second language acquisition from animations (e.g., Roche & Scheller, 2008), but none on first language learning.

In sum, based on the above review of the literature, we propose that the effectiveness of grammar animations could be enhanced through gestures. Gestures are assumed to activate the motor system, thereby lightening cognitive load and enhancing learning. It should be noted that this beneficial effect on cognitive load and learning is not necessarily expected for children with all levels of expertise on the subject matter. First, it is plausible that learning of grammar rules is better for children with higher general language skills than for children with lower general language skills. Second, the effect of gestures could potentially differ between children depending on their level of language skills. That is, research on the expertise reversal effect (Kalyuga, Ayres, Chandler, & Sweller, 2003) has shown that an instructional format may cause different effects on cognitive load and learning for learners with different levels of expertise. For instance, in a study on acquiring skills to use a database program, novices were found to benefit more from worked examples, whereas more experienced learners had equal learning benefits from worked examples as from exploration; the worked-out steps were redundant for them and no longer contributed to their learning (Tuovinen & Sweller, 1999; see also Kalyuga, Chandler, Tuovinen, & Sweller, 2001).

Considering the present study this could mean that instructions to gesture might be effective for children with lower, but not for children with higher levels of language skills, for whom gestures might be redundant. The opposite might also be possible, that instructions to make gestures impose additional load, which might be beneficial for higher level learners (i.e., germane load) but might cause such high load for lower level learners, that it impairs their learning. Given that there is no prior research in this area, it is hard to predict whether language skills have an effect and if so, in which direction, but research on the expertise reversal effect suggests it is important to consider level of language skills as a factor (instead of a covariate).

In sum, the present study combines the use of gestures and animations in language acquisition. The question that is being examined is whether simultaneously observing and making gestures while studying animations, contributes to grammar learning. This experiment focuses on teaching children which grammatical rules are involved in the transformation of an active sentence (e.g., 'Pete is petting the dog') into a passive sentence (e.g., 'The dog is being petted by Pete') through animations. It is hypothesized that children will experience lower cognitive load and perform better on both an immediate and delayed (after one week) posttest when they saw and made gestures while studying animations. Depending on the amount of forgetting, an interaction of Condition and Posttest might occur. That is, it could be that gestures lead to less forgetting, which would become evident through an interaction effect. However, it can also be that both groups show similar forgetting. In that case, there will be no interaction. Motivation and perceived difficulty were assessed as a check, as these variables might provide alternative explanations for possible cognitive load and learning effects when they would differ between conditions. Finally, in light of the expertise reversal effect, effects of levels of language skill will be explored.

2. Method

2.1. Participants and design

Sixty-nine Dutch primary school children in grade 6 participated in the experiment, they came from four classrooms in two schools. Two participants were excluded from all analyses because teachers stated that their IQ was extremely low ($\leqslant 70$). The age of the 67 remaining participants ranged from 10 to 13 years ($M = 11.57$, $SD = .70$) and 34 of the participants were boys. All children were born in the Netherlands and were sufficiently fluent in Dutch to understand the instructions and participate in the experiment. Fifteen children had one or two parents who were not born in the Netherlands. Five participants were absent during the second session and were therefore excluded from analyses concerning the delayed posttest (i.e. all performance measures).

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