The effect of gestured instruction on the learning of physical causality problems

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Recent research has demonstrated instruction that includes gesture can greatly impact the learning of certain mathematics tasks for children and much of this work relies on face-to-face instruction. We extend the work on this problem by asking how gesture in instruction impacts adult learning from a video production for a science concept. Borrowing from research by Perry and Elder (1997), the research presented here examines what role adding gesture to instruction plays for adults learning about gear movement. In this pretest-instruction-posttest design, 56 college-aged participants were asked to complete problems relating to gear movement. Participants viewed either an instructional video in which an instructor used speech only (control) or speech-plus-gesture (experimental) to explain a fundamental principle in the physics of gear movement. Results showed that adults who knew less actually learned more and that instruction was effective, but significantly more effective when gesture was added. These findings shed light on the role of gesture input in adult learning and carry implications for how gesture may be utilized in asynchronous instruction with adults.

Keywords: instruction, adult learning, physics learning

What is the role of gesture in enhancing instructors' ability to help students learn? Does an instructor's gesture add significantly to students' developing understanding of a concept? Gesture is often part-and-parcel of the learner's experience when learning to solve problems, but the impact of these gestures has received surprisingly little attention in understanding these instructional situations. In general, research investigating instructional interactions focuses on the verbal aspect of instruction and typically neglects nonverbal contributions, although recent work suggests that gesture may play a pivotal role in helping students learn (Alibali &

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Nathan, 2011; Goldin-Meadow, 2003). The focus on verbal information, although an excellent place to start, fails to take into account critical information in the instructional setting. Independent researchers have found that speech does not often occur alone, but is most typically accompanied by "co-speech gestures" or manual movements that illustrate, in imagistic form, content represented in speech (Alibali & Nathan, 2011; Ekman & Friesen, 1974; Goldin-Meadow, 2003; Kelly, Manning, & Rodak, 2008; Kendon, 2004; McNeill, 1992, 2005; Reilly & Muzekari, 1986; Thompson & Massaro, 1994).

Gestures are frequently produced during communication, but does this mean that listeners or observers actually process and then use that gestural information? It turns out that both children and adults detect gesture produced along with speech (Church, Garber, & Rogalski, 2007; Goldin-Meadow, Wein, & Chang, 1992; Kelly & Church, 1997, 1998; Perry, Woolley, & Ifcher, 1995; Ping, Goldin-Meadow, & Beilock, 2013; Quandt, Marshall, Shipley, Beilock, & Goldin-Meadow, 2012). Moreover, studies have shown that when children and adult listeners observe speech with accompanying gesture, their processing and retention of speech is improved (Barr, Kelly, Church, & Lynch, 1999; Church et al., 2007; Church, Kelly, & Lynch, 2000). Thus, gesture that accompanies speech during communication appears to improve a listener's comprehension of a message.

The tendency to process co-speech gestures appears to have implications for communication produced during teaching interactions. Research that has examined solving problems in mathematics and science, pertinent to the current investigation, demonstrates that certain gestured input can be influential in producing learning and cognitive change (Church, Ayman-Nolley, & Mahootian, 2004; Cook, Duffy, & Fenn, 2013; Cook & Goldin-Meadow, 2006; Goldin-Meadow & Singer, 2003; Singer & Goldin-Meadow, 2005; Valenzeno, Alibali, & Klatzky, 2003). The reason gesture may be important in learning to solve problems in mathematics and science is that gesture can serve important representational functions (Alibali & Nathan, 2011; Church et al., 2004; Cook et al., 2013; Goldin-Meadow, 2011; Goldin–Meadow, Alibali, & Church, 1993) that potentially convey information critical to the instructional situation, which may not be readily available in speech. According to Corballis (1999), "[g]esture supplies a visual, iconic component that can provide extra information or circumvent prolonged explanation" (1999, p. 142). Gesture can also augment spoken information in a variety of ways, illustrating words through imagery (Singer, Radinsky, & Goldman, 2008), establishing joint attention to relevant contextual references between the teacher and the learner (Alibali & Nathan, 2011; Reynolds & Reeve, 2001), or drawing attention to aspects of what is produced in speech (Alibali & Nathan, 2011; Woodall & Folger, 1985). This work adds much to the research on effective instruction but it is limited in that most of the focus has been on teaching children in face-to-face situations. It is also worth knowing whether these same effects can be obtained in adults and in asynchronous instructional situations, such as online instruction.

It is clear that learning takes place beyond childhood, however it is unclear whether adult learners require the same learning supports as children. Research on adult learners suggests that older adults naturally compensate when their skills or conditions in the learning situation are not optimal for the task (e.g., Stine-Morrow, 2007), so gesture may not be as important for older learners as it is for child learners. However, research that examines gestures in adults suggests quite the opposite. Rather than gesture declining and simplifying with age, gesture increases and becomes more complex (McNeill, 1992). Moreover, considerable data on adults show that adults produce gesture when actively engaged in problem solving (Chu & Kita, 2008, 2011; Schwartz & Black, 1999). The suggestion here is that, even with adults, gesture production can provide insights about cognitive processes during problem solving (e.g., Chu & Kita, 2008, 2011; Schwartz & Black, 1999). Note that these previous studies focused on gesture production in adults, whereas we are concerned with the effect of gestured input that adults receive.

Examining adult learning can inform us about the generality of learning principles across development (Perry & Elder, 1997). Recently, promising research in the domain of video modeling has examined the role of observational learning in adults' learning of science concepts (in particular, computer and physics problems; e.g., Chi, Roy, & Hausmann, 2008; Craig et al., 2009; Gholson & Craig, 2006). Although research has described adults' ability to learn from watching instruction on screen, examination of the role that gesture plays in instruction for adults has been infrequently studied in an experimental setting (Alibali, Spencer, Knox, & Kita, 2011; Perry & Elder, 1997; Stürmer, Aschersleben, & Prinz, 2000; see also Hostetter, 2011, for a comprehensive review of studies examining gesture's benefit on learning). Given that gesture is ubiquitous in communication and quite common in teaching interactions, we ask what role gesture may play as *input* to the adult learner in problem-solving situations and specifically ask whether gesture may support learning in adults.

Previous research has examined gestured instruction using a variety of media, but most of this work has been conducted on face-to-face instruction (e.g., Cook & Goldin-Meadow, 2006). For many reasons, we focus on learning from video instruction. Instruction delivered via video has several distinct advantages, including the standardization of instruction and the insights it can provide to learning in online contexts.

One reason we focus on video-based instruction is that it has become highly relevant to the phenomenon of online instruction, which has substantial popularity as an educational medium. Online teaching is seen as a viable alternative to face-to-face teaching for a host of reasons (Allen & Seaman, 2006, 2010). However, there has been surprisingly little research investigating the effect of gestured instruction on learning in video-streamed situations.

Video-streamed, problem-solving instruction has been produced in various ways including having voice accompanying manual manipulations of problem-solving on screen (e.g., Craig, Chi, & Van Lehn, 2009), voice accompanying a shot of the face with no inclusion of body movements (i.e., talking heads), but sometimes, no description is provided of what exactly was presented on screen (e.g., Roseth, Salatrelli, & Glass, 2011). In contrast, observations of natural teaching events show an impressive amount of gesture production by both instructors and students during discussion of mathematical and scientific topics, suggesting that representational gesture may provide an important communicative function particularly for mathematics and science learning (as was suggested earlier). Although instructional video may include gestures accompanying speech, we sought to standardize this and explicitly examine the effects of speech with or without gesture in an instructional video.

We chose to investigate the effects of gesture on adults learning from video in the context of solving gear movement problems. These problems are useful for examining gesture instruction and adult learning for a variety of reasons. First, the problem of gear movement is an operationalization of a fundamental physics principle, that of physical causality, a concept whose acquisition is not limited to a particular point in development but can be mastered throughout development, and is often not well understood by adults (e.g., Alibali et al., 2011; Perry & Elder, 1997) and gesture may make obvious exactly how the gears move in ways that are difficult to see in speech. Second, gear problems have been used to assess representational change in both children (Dixon & Bangert, 2002) and adults (Alibali et al., 2011; Schwartz & Black, 1999). Therefore, observing adults learning to solve gear problems seemed like an excellent context in which to explore the effects of gesture on representational change. Third, gear problems provide a rich context for understanding the particular role of gestures in instruction because most adults do not talk about gear movement on a regular basis and often rely on gestures in their communication about gears (Perry & Elder, 1997). A typical procedure for presenting this type of problem is to present a diagram depicting an array of gears and ask the learner to predict which direction a designated gear will rotate if the initiating gear is turned in a particular direction. This type of problem requires a mental simulation of action to solve the problem successfully (Schwartz & Black, 1999) and the availability of observing the simulated rotation in gesture may support understanding the principle of gear movement. In the absence of being able to rotate the gears physically to solve the problems, individuals (both children and adults) typically gesture in ways that suggest that the person solving this problem is simulating the rotation of the gears (Schwartz & Black, 1999). The learner uses his or her own gesture as cognitive support for the simulation that he or she cannot accomplish through physical movement of the gears. Given the tendency of individuals to spontaneously use gestures to work through gear problems, we would predict that instruction that included gesture simulating the rotating action of the gears should be particularly effective for enhancing understanding of gear movement.

Method

Participants

Sixty-one adults (17 males and 44 females) attending a non-residential university participated in this experiment. The university is a medium-sized (~9,000 undergraduate students) public state university in a major urban area. The university is a highly diverse, federally designated Hispanic serving commuter school with a large population of older and non-traditional students. All participants were Psychology majors and received credit for their participation. The diversity of Psychology students reflects the diversity within the university; approximately 58% of Psychology students are from underrepresented minority groups (predominantly Latinos). Five of the participants were able to solve all of the pretest problems so they were excluded from the analyses, leaving 56 (15 males and 41 females) participants for further investigation.

Materials

The gear problems. All gear problems used in this study are identical to the ones used in Perry and Elder's (1997) study. Two warm-up gear problems were administered to the participants along with a pretest and posttest (see Figure 1 and the Appendix). The pretest and posttest questions on the posttest were identical; however, the direction of the gear with the handle was reversed.

The problems in the pretest reflected various degrees of complexity and transfer of the 2 basic principles of gear movement: (1) gears connected in a linear way will move in opposite directions and (2) if gears are interconnected in a non-linear configuration, a gear that is interlocked with two or more gears will not move if an odd-number of gears are joined together.

Video stimuli. Two instructional videos were created and used in this study. The instructional speech that we used is nearly identical to the speech used by the instructor in Perry and Elder's (1997) study. In the present investigation, we added information to the speech-only instruction, as Perry and Elder had gesture

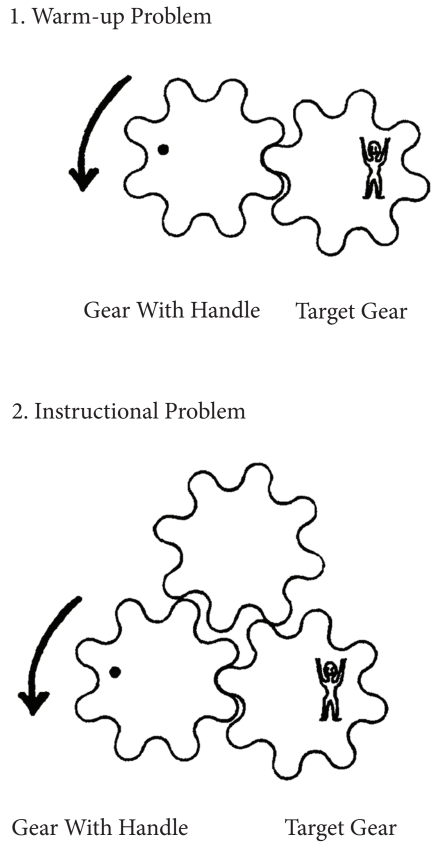

Figure 1.

available in their instruction and we needed to make the speech-only instruction sufficient on its own.

In one video, only speech instruction of these principles was presented (the speech-only condition). Note that we intended to keep the *speech only* video authentic, much like typical asynchronous teaching experiences, and, as such, featured the gear problems with the voice of the instructor providing instruction on how to solve gear problems. In the other video, the identical speech transcript for instruction was presented with only the instructor's hand and arm directed toward the pictures of the gears (speech-plus-gesture). The instructor's face and body was omitted from the screen, given that facial information can mediate the role of gesture in communication (Gullberg & Holmqvist, 2006). In both videos, the instructor explained a principle of gear movement (detailed, below). We reiterate that the speech instruction transcript was identical across these two video stimuli. We did several takes of the instructional videos so that the speech instruction would be indistinguishable in terms of intonation, timing, and stress across the video instructional tapes — and the only feature that would distinguish the two conditions was the presence of the instructor's hands (present in the speech-plus-gesture condition and absent in the speech-only condition).

The speech instruction contained the necessary principles of gear rotation for the participants to correctly solve the problems (i.e., the nonverbal accompaniment was not necessary to understand the instruction). Simulating a typical asynchronous learning environment, each participant viewed the instructional video on a laptop (a 14" Macbook Pro). Below is a verbatim description of the instruction that the adult subject heard and saw. The exact transcription of the speech is presented for both instructional videos. Inserted in italicized text is a description of the gestures produced in the speech plus gesture instructional video.

> Now I'm going to tell you something about gears. Look at these two gears (see Figure 1 for the warm-up problem). When gears move, it's because something's being pushed. So what happens with gears is that when they move, one gear's teeth are pushing [*the instructor makes an arced motion with his index finger, signifying the directional push of the indicated gear's teeth on another's*] against another gear's teeth. When we need a way to figure out what will happen to the gear with the person on it, one way of thinking about this is to think about the teeth. The teeth of the gear with the handle, push [*the instructor makes an arced motion with his index finger, signifying the directional push of the indicated gear's teeth on another's*] against the teeth of each gear they touch. In the same way, the teeth of each and every gear will push [*the instructor makes an arced motion with his index finger, signifying the directional push of the indicated gear's teeth on another's*] against the teeth of each gear *they* touch.
> For example, in this illustration (see warm-up problem), the gear with the handle moves counter-clockwise [*the instructor indicates a counter-clockwise motion with his index finger around the circumference of the gear with the handle*], and therefore the teeth of the gear with the handle push [*the instructor makes a motion with his index finger, signifying the directional push of the indicated gear's teeth on another's*] against the teeth of the target gear, which in turn moves the target gear in a clockwise motion [*the instructor indicates a clockwise motion with his index finger around the circumference of the target gear*].
> Now I'm going to add a third gear (see Instructional Problem in Figure 1). Remember, the teeth of one gear push against the teeth of each gear they touch. With this in mind, let us look at the following example. If the teeth of the gear with the handle move counter-clockwise [*the instructor indicates a counter-clockwise motion with his index finger around the circumference of the gear with the handle*], they will push [*the instructor makes a motion with his index finger, signifying the directional push of the indicated gear's teeth on another's*] the teeth of the target gear clockwise [*the instructor indicates a clockwise motion with his index finger*

> *around the circumference of the target gear*]. Unfortunately for these two gears though, the third gear's teeth come into contact with both the teeth of the gear with the handle, which are rotating counter-clockwise [*the instructor indicates a counter-clockwise motion with his index finger around the circumference of the gear with the handle*], and the teeth of the target gear, which are rotating clockwise [*the instructor indicates a clockwise motion with his index finger around the circumference of the target gear*], therefore making the third gear's teeth unable [*instructor makes a chest level sweeping (left to right) motion with his hand flat and his palm pointing towards the floor*] to move in any direction.

The gestures provided by the instructor, as indicated in the italicized text, were designed to help our adult learners conceptualize the principle of gear movement — that gears connected in a linear array will move in opposite directions — in an iconic way. The gestural simulation of the gears rotating, one gear rotating in one direction impacting on the contiguous gear resulting in a rotation in the opposite direction, we felt would help the learner visualize the gear movements.

Design

This was a pretest-instruction-posttest, between-subjects design. The independent variable was instruction with two levels: speech-only and speech-plus-gesture. The dependent variable was the evidence of learning after being exposed to an instructional video.

Procedure

Pretest. Each participant was tested individually. A participant was informed that he or she would solve gear problems in the study. The participant was shown one warm-up problem. The experimenter explained to the participant that he or she should mark the target gear (indicated by a person-like figure) with an arrow, signifying which direction the target gear would turn if the gear with the "handle" (indicated by a large dot) was turned in the indicated direction. The participant was asked to mark the direction of the target gear with a clockwise or counter-clockwise arrow, indicating the way in which the target gear would turn, or with an "X" if the target gear would be unable to move. The participants were then asked to complete the warm-up gear problem that was provided. After the participant finished the warm-up problem he or she was asked to complete seven gear problems.

Instruction. After the pretest, the participant was randomly assigned to one of the two instructional video conditions in which an instructor provided an elementary instruction on gear movement. Again, to simulate online learning conditions, the participant was asked to wear headphones while watching the video.

Posttest. After watching the video, participants then completed a posttest of 7 gear problems. These problems were almost identical to the pretest problems; the difference was that the initial gear with the handle was turning in the opposite direction from what was presented on the pretest.

Results

For all analyses, we removed participants who received a perfect score on the pretest. We did this because they were at ceiling and therefore could not demonstrate improvement after instruction. After removing these 5 participants, there remained 26 participants in the speech-only condition and 30 participants in the speech-plus-gestures condition.

Before examining effects of instruction on performance, we compared the participants in the two instructional groups for two background characteristics — gender and pretest understanding — that potentially could confound the effect of instruction, to determine if these background characteristics were equally distributed across the two instructional groups. We found that there were no differences in distribution of gender or pretest knowledge across the instructional groups. Each condition contained approximately the same distribution of males (30%) and females (70%), $\chi^2 = .03$, $p > .05$).

Problem 4, although intended to be much like the other non-linear configurations, presented atypical difficulties for most participants. We suspect that the segment of the instruction that told participants "the third gear's teeth come into contact with both [gears], therefore making the third gear's teeth unable to move in any direction" may have confused some participants and led them to believe that any configuration with a closed loop would be a frustrated system and not move. We conducted analyses with and without Problem 4, and obtained the same results. However, because of the potential ambiguity of our instruction and the large number of participants who interpreted our instruction in an incorrect way, we have omitted problem 4 from all analyses.

Instructional effects

Before instruction, participants in the speech-only condition produced an average of 2.9 correct solutions on the pretest ($SD = 1.02$). Participants in the speech-plus-gesture condition also produced an average of 2.9 correct solutions on the pretest ($SD = 1.27$), $t(54) = .074$, $p > .05$.

Was the instruction effective, independent of condition? We found that the video instruction (both when the instruction was accompanied by gesture and when it was not) produced learning. As we just noted, the average number of correct solutions at pretest was 2.9 *(SD* = 1.15). At posttest, the average number of correct solutions (across both conditions) was 4.55 *(SD* = 1.22), resulting in a statistically significant difference between the pre- and posttest, paired $t(55) = 8.41$, $p < .001$.

Did speech-plus-gesture instruction result in more learning than speech-only instruction? At the posttest, participants in the speech-only condition produced an average of 4.0 correct solutions ($SD = 1.24$) and participants in the speech-plus-gestures condition produced an average of 5.0 correct solutions at posttest ($SD = 1.08$). We conducted a repeated measures ANOVA, with time (pretest/posttest) as the within-subjects factor and condition as the between-subjects factor and found that participants exposed to the speech-plus-gesture instruction showed significantly higher gains ($M = 2.03$, $SD = 1.45$) than participants exposed to the speech-only instruction ($M = 1.19$, $SD = 1.36$), $F = 4.97$, $p < .05$).

Was there an effect of prior knowledge on learning? Although we found no differences between conditions at pretest for number of correct solutions, individual participants' ability to learn could have been affected by their prior knowledge, and this could have interacted with the instruction. To examine this possibility, we conducted a between-subjects two-way ANOVA, and included participants' initial knowledge status in the model, with gain score as the outcome variable. Gain scores reflected the difference in correct solutions between participants' pretest and posttest. For this analysis, we chose to look at the first three problems as a set because these problems were much simpler than the remaining problems. Thus, knowledge status was categorized as low if a participant solved any of the first three problems incorrectly or high if participants answered problems 1–3 correctly on the pretest.

We found a main effect of knowledge status. Participants with low knowledge status gained significantly more ($M = 5$) than those with high knowledge status ($M = 3$); $F = 5.77$, $p < .05$.

Adding support to the treatment effects analysis, there was a main effect of condition with the participants exposed to the speech-plus-gesture video instruction gaining significantly more than adults exposed to the speech-only video instruction regardless of their pretest knowledge of the gear problems, $F = 5.23$, $p < .05$. There was no interaction between knowledge status and condition ($F = 0$, $p = .99$, see Figure 2) suggesting that instruction was showing effects on learning regardless of the prior knowledge status of the learner. Although ANOVAs are fairly robust against abnormal distributions, it is important to note we also conducted a non-parametric two-way ANOVA, which while less powerful does not assume a normal distribution. This analysis revealed the same main effect of condition, $F = 5.13$, $p < .05$ and basically the same result for knowledge status, $F = 3.89$, $p = .05$. The interaction remained non-significant, $F = .14$, $p = .71$.

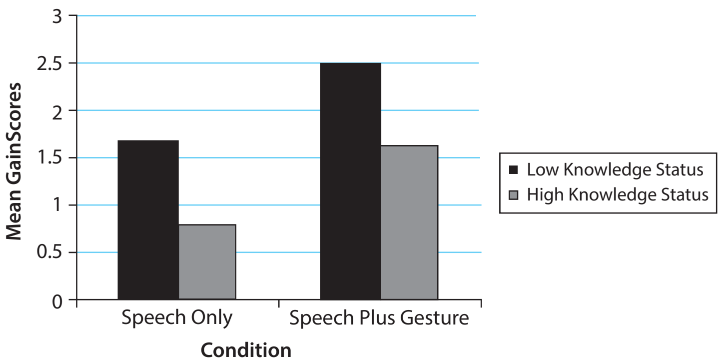

Figure 2. Interaction of condition × knowledge status for gain score.

Discussion

In the present investigation, we purposefully showed adult participants an instructional video about gear movement with explicit speech instruction. Some participants experienced this video *without gestures* and other adult participants experienced this video *with gestures*. We found that, in general, the video instruction improved performance from pre- to posttest and the instruction that included gesture improved performance more than instruction that did not include gesture.

Alibali (Alibali & Nathan, 2007; Alibali, Nathan, & Fujimori, 2011) and others (e.g., Flevares & Perry, 2001) have found that teachers frequently use gestures during instruction. In naturalistic studies, however, it is very difficult to directly link learning with a teacher's use of gestures. This study experimentally demonstrated the effectiveness of gesture for instruction of principles of gear movement, expanding beyond other research.

Why might gesture enhance instruction while teaching adults?

These results replicate a number of previous studies that examined the influence of gestured instruction on learning with children (e.g., Church et al., 2004; Cook et al., 2013; Cook & Goldin-Meadow, 2006; Goldin-Meadow & Singer, 2003) and extend these results to adults learning to solve problems of physical causality involving gears. This provides support for the hypothesis that gesture may be a general factor that supports or even drives change (Goldin-Meadow, 2003), not just for children but for adults as well.

Although this particular investigation was limited to testing the effectiveness of gesture for a concept that is spatial in nature, we note that gesture appears to both reflect and augment cognitive change in non-spatial domains as well, including early language acquisition (Morford & Goldin-Meadow, 1992), story narration (Cassell, McNeill, & McCullough, 1999), and social reasoning (Church, Schonert-Reichl, Goodman, Kelly, & Ayman-Nolley, 1995). So why is gesture during instruction so helpful for learners?

McNeill (1992) and Kendon (2004) argue that gesture occurring with speech, while working hand in hand with speech, reflects a very different version of the source thought or idea than speech. Gesture reflects the gestalt, three-dimensional version of thought while speech reflects the linguistically ruled, linear and segmented version of thought (Kendon, 2004; McNeill, 1992). In this way, one could argue that gesture reflects the sensory-motor or embodied representation of an idea while speech reflects an abstract, generalized version of an idea. Embodiment theory (e.g., Lakoff & Nunez, 2000) suggests that conceptual understanding requires sensory-motor knowledge as the infrastructure for those higher level reflective representations. In this way, gesture may provide a level of input not available in speech, which helps the learner acquire and integrate new knowledge.

Besides the specific information carried in gestured representations, adding an embodied aspect to instruction may also be playing a role in impacting learning outcomes. For example, research in mathematics education has argued that experiential learning is important for the construction of mathematical knowledge (e.g., Ben-Zeev & Star, 2001; Piaget, 1954). Teaching the application of mathematics to real life and enhancing a learner's active role in the learning process has been theorized to lead to a deep conceptual understanding (Lakoff & Nunez, 2000). In fact, studies that examine gestured input in instruction of mathematics have shown that instruction with gesture results in deeper and longer-lasting learning than instruction with speech only (Cook et al., 2013; Cook, Mitchell, & Goldin-Meadow, 2008). In the case of learning about gear movement, the iconicity of the gestures, directly showing one gear turning clockwise, may have provided these learners with a visual representation of the action, which is not available from the static picture and gives clear information that may be better understood as action than the verbal description of the action in speech. From the research presented here, we could construe that instruction that activates sensory modalities in tandem — such as audition (hearing speech) and vision (viewing gesture) — would facilitate mathematical understanding.

We also acknowledge that the gesture could have served to manage the attention and not necessarily provide a sensorimotor grounding for the learners. To address this point, we recommend directly comparing the same verbal instruction paired with deictic or with iconic gestures. Although this issue remains unresolved, other work in mathematics teaching and learning (Bem et al., 2012) has found that a computerized highlighting modeled after gesture during instruction on polynomials did not help learners, but the gesture did help improve performance on solving the polynomials. Thus, we suspect that gesture, in the current investigation, provided a benefit to learners beyond its ability to help manage attention and, instead, advanced students understanding by augmenting their perceptions of gear movement.

It is important to note that gestured instruction may not always be beneficial to potential learners. Beilock and Goldin-Meadow (2010) suggest that gesture may *not* be beneficial for learners who possess some partial understanding of a particular concept. This suggests that gesture may only be beneficial if it provides conceptual infrastructure where there was none. If a learner has some infrastructure, as in those who may have partial or inconsistent understanding of a particular concept, gesture may not be helpful. Note however, in our study that gesture enhanced learning in both learners who had little knowledge about gear movement and in those who had quite a bit understanding. We would caution that gestured input might not have consistent effects across all concepts or tasks. One important question to be examined is just how generalizable the impact of gesture is across ages, discourse contexts, and concepts.

We argue that with respect to the physical causality problems, where representations of gear movement may be particularly grounded in hands-on experience, the addition of gestures may stimulate the learner's connection to the learning materials. We suggest this possibility because there has been research demonstrating that observing another's gestures activates the observer's own motor system and that this activation can have consequences for the observer's understanding of certain types of problems (Ping et al., 2013; Quandt et al., 2012). Our results suggest that the impact of gestured instruction possibly provoked the adults in our study to recruit their own sensory-motor systems in a way that positively impacted their ability to solve these gear problems. Gesture combined with speech during instruction may help the observing learner link a sensory-motor representation with a speech representation.

Application to education

Recent research has focused on video tutoring models as an important technological innovation in learning (Craig et al., 2009). The research on tutoring argues that the most influential factors in video tutoring are the content of the video itself (as opposed to socio-contextual factors; Klahr & Nigam, 2004). However, in prior work, the verbal and nonverbal content was not subject to examination when determining effectiveness of video instruction to convey information. Pairing images with an abstract concept conveyed in speech may provide the necessary hook to make an abstract and opaque concept accessible (Mayer, 2009).

We note that this research was done with a typical population, in a college setting with a diverse population of adults. Moreover, our sample was predominately female (although the distribution of genders was comparable across conditions). Thus, we caution against generalizing our findings beyond a sample of diverse, mostly female college students. We wholeheartedly recommend conducting this investigation with older adults, as well, to see the extent to which older versus younger adults take advantage of the video versus compensate for the relative lack of information in the speech-only condition (see Stine-Morrow, 2007).

We also note that while the video instruction was presented on a computer, which is typical for online learning situations, we did not explicitly compare the instruction to a face-to-face condition, where the instructor and learner may respond to each other's cues. Thus, while we would hypothesize that online instruction that includes a gestured component would likely positively impact learning, we can make no claims about the relative benefits of experiencing that instruction versus experiencing instruction in a face-to-face setting.

Research has hardly grazed the surface of understanding the role gesture plays in the context of live versus in video-streamed communication. One study however, illuminated the complexity of this question by examining visual attention (measured through eye-tracking) of addressees in the context listening to story narrations (Gullberg & Holmqvist. 2006). Surprisingly, very little visual attention was focused on gestures, with more attention being focused on the face of a speaker. Moreover, less attention was fixated on gesture produced in video than live. Because our video stimuli did not have facial information to distract our participants, this might explain the significant impact of gestured instruction. Although Gullberg and Holmqvist's study did not look at gesture in an instructional context, it does point out the need to be careful in the inferences made about the impact of gesture input.

Summary

We asked whether gesture supported adults' learning about physical causality when shown this information in a scripted video presentation. We found evidence of learning from video, which suggests that adult learners can extract useful information without receiving personal feedback and without other nuanced and social cues that are available in face-to-face instructional situations. We also found that the addition of standardized gestures led to better learning outcomes than the video instruction without gestures. Because of the nature of representational gestures used in this study, the authors suggest that representational gesture may be a very useful supplement to speech when teaching adults who are grappling with a new idea. Although gestures are a frequent part of classroom communication (e.g., Alibali et al., 2009; Goldin-Meadow, Kim, & Singer, 1999), very little research has examined gesture's role during instruction. This research contributes to our understanding of the role gesture plays in instructional contexts.

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Appendix A.

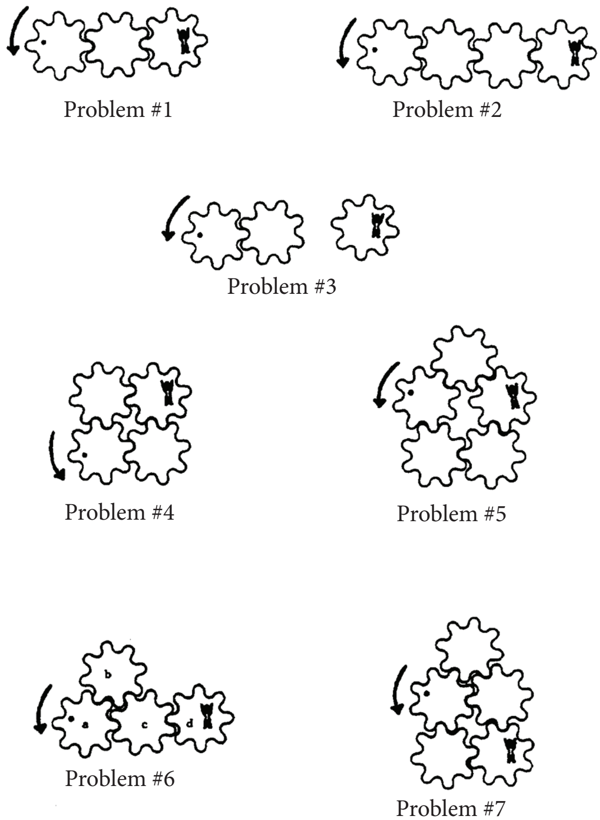

Figure 3. Pre- and posttest

We used identical configurations from the pretest for the posttest. For the posttest, we changed the direction the gear with the "handle" was shown to move, so that it appeared to be turning in the opposite direction compared to the pretest, thereby changing the ultimate direction of the target gear from the pre- to the posttest.

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Michelle Perry is full professor in the Department of Educational Psychology and in the Beckman Institute for Advanced Science and Technology at the University of Illinois at Urbana-Champaign. Her research is focused on the acquisition of mathematical and scientific concepts and the contextual factors — including instruction — that supports their acquisition.

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