The Effect of Inhibiting Hand Gestures on Mathematical Reasoning

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Abstract: Gestures are associated with powerful forms of mathematical understanding. However, determining the causative role of gestures has been more elusive. In the present study, we inhibit students' gestures by restraining their hands, and examine how this impacts their problem-solving when presented with geometric conjectures to prove. We find no effect for gesture inhibition across a variety of measures.

Background

Embodied views of cognition posit that mental processes are rooted in perceptual and motor systems (Wilson, 2002). One way in which mathematical reasoning is embodied is through gesture. Learners' tendency to gesture predicts learning and performance in mathematics (Cook & Goldin-Meadow, 2006), and recent studies in geometry specifically have suggested that students who gesture more and who gesture in specific ways tend to communicate more accurate geometry proofs (Nathan et al., 2014; Nathan & Walkington, 2017). However, it is unclear from such prior work on gestures whether gestures are simply a byproduct of valid mathematical reasoning, or a causative factor. One way to experimentally manipulate gesture is through gesture inhibition.

Inhibiting gestures by having learners tap in patterns while solving problems leads to weaker performance (Hegarty et al., 2005). Inhibition methods where the hands are restrained have been found to impair simple recall (Frick-Horbury & Guttentag, 1998; Goldin-Meadow et al., 2001; Wagner et al., 2004) and fluency of speech with spatial content (Rauscher et al., 1996). Prior research has not examined how gesture inhibition impacts *mathematical reasoning,* which has important visual, spatial, and motoric properties. Research has also not examined whether effects vary based on learner characteristics. Here we examine how inhibiting gesture impacts mathematical reasoning and speech. Our research questions are:

1) How do speech patterns and recall vary when learners are inhibited or not inhibited from gesturing?
2) How does gesture inhibition impact performance on geometry proof tasks?

Methods

Undergraduate and graduate students (n = 107, 48 male and 59 female, 50 STEM majors) from a private university were recruited to participate. After pre-measures (geometry pre-test, spatial visualization test, phonemic fluency test), they were presented with 8 geometry conjectures to prove (e.g., the triangle inequality) while standing in an empty room. For 4 of the 8 conjectures, they were inhibited from gesturing by putting their hands in oven mitts attached to bottles attached to a music stand. When they completed all 8 conjectures, participants were asked to, while uninhibited, recall as many of the conjectures as possible.

Participants were video recorded and their speech was transcribed in Transana. Participants' oral proofs for each conjecture were scored 0/1 in terms of correct or incorrect using a codebook developed from the criteria for valid mathematical proofs given by Harel and Sowder (2005). Valid proofs involve (1) operational thought, where provers perform valid operations on mathematical objects and observe their results, (2) logical inference, where provers progress through a deductive structure, and (3) generality, where provers show the conjecture holds for all cases. Inter-rater reliability (kappa) of .80 was achieved. The transcripts of participant speech were entered into Coh-metrix (McNamara, Louwerse, Cai, & Graesser, 2013) and LIWC (Pennebaker et al. 2007).

Data were analyzed using mixed effects logistic regression models. Random effects included participant, conjecture, and order. Controls included gender, language status, and highest prior math course. Expertise variables included geometry pretest score, spatial visualization score, STEM/non-STEM major, and phonemic fluency score. Whether the participant was inhibited or not inhibited for the trial was the treatment variable of interest. Speech predictors were not tested in regression models, due to screening t-tests of 155 different language measures all showing null results for the difference between inhibited and uninhibited trials.

Results

Analyses showed that gesture inhibition had no impact on any of the 155 speech categories measured by the text-mining tools. Gesture inhibition had no effect on either conjecture recall or on participants' ability to formulate a valid intuition (defined as a correct true/false judgment), insight (defined as a partially correct proof), or proof for a geometry conjecture. These results run counter to other gesture inhibition studies in other domains. There were no significant interactions between inhibition and student expertise or control variables.

Discussion and significance

Prior research has suggested relatively uniform, detrimental effects for gesture inhibition on language and recall tasks, but few studies have examined how being prevented from gesturing impacts complex problem solving in a domain like secondary mathematics. In addition, prior research has shown that gesturing is generally associated with formulating valid geometric proofs (Nathan et al., 2014), but here we directly manipulate gesture to make inferential claims. We discovered that gesture inhibition has no effect on a variety of outcome measures – including speech patterns when justifying geometric conjectures, tendency to be able to recall a conjecture, and giving valid intuitions, insights, and proofs for conjectures. Analyses of interaction effects suggested gesture inhibition had no effect regardless of gender, language status, geometry knowledge, spatial skills, phonemic fluency, college major, or math course-taking history. However, we did find that even when their hands were inhibited, participants still made mathematical gestures with their heads, eyes, shoulders, etc., suggesting that the utility of gesture inhibition through hand restraint may be somewhat limited.

One explanation for this set of findings is that gesture is merely a byproduct of – rather than a causative factor in – valid geometric reasoning. In other analyses, we found that students who tended to do better at these geometry tasks also tended to gesture more. But these results suggest their gestures were not *influencing* or *causing* their valid reasoning. Thus, promoting completely unstructured, undirected gesture may not be an ideal approach to support embodied reasoning. Instead, gestural interventions should consider carefully how students can be instructed to or encouraged to gesture in particular, productive ways.

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