KINECTING GEOMETRIC PROOF CONCEPTS USING GESTURES

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We explore whether *directed actions*—body movements that learners are instructed to formulate—enhance mathematical reasoning during proof production. Evidence is mounting that sensorimotor activity can activate neural systems, which can in turn alter and induce cognitive states (Nathan, 2014). New interventions are using motion-sensing technology to track actions that support geometric reasoning (e.g., Smith, King, & Hoyte, 2014). We directed learners to perform mathematically-relevant (vs. irrelevant) motions through motion-capture video game play and hypothesized (H1) that directed actions will facilitate production of dynamic gestures, which will, in turn, (H2) improve students' nonverbal mathematical insights and the production of multimodal transformational proofs. Moreover, we hypothesized (H3) that adding pedagogical hints explicitly connecting directed actions to the conjectures enhances proof performance.

Thirty-five middle and high school students played the *Hidden Village* game for the Kinect. Students played through 6 conjectures, with 2 to 4 conjectures (with relevant motions) revisited where the interviewer revealed to students how the motions related to the conjectures. Students' responses were scored along 4 dimensions: (1) making spontaneous *depictive* gestures, (2) making spontaneous *dynamic* depictive gestures, (3) recognizing key mathematical *insights*, (4) formulation of a *valid* transformational proofs (Harel & Sowder, 1998).

Participants were more likely to make depictive gestures when performing mathematically relevant (vs. irrelevant) directed actions (Odds=4.2, d=0.8, p=.008). Participants who performed relevant directed actions were *not* more likely to make dynamic gestures (H1), demonstrate the mathematical insight, or provide a valid proof (H2; $p > 0.1$). However, after receiving the pedagogical hint (H3), participants were more likely to make depictive gestures (Odds=5.4, d=0.9, p<.001), dynamic gestures (Odds=4.0, d=0.8, p=.001), more likely to express the correct insight (Odds=3.1, d=0.6, p<.001), and more likely to formulate a valid proof (Odds=4.7, d=0.9, p<.001). Producing depictive gestures predicted mathematical insight (Odds=3.0, d=0.6, p=.007), but not formulating a transformational proof. However, making *dynamic* depictive gestures (H2) predicted both insight (Odds=8.1, d=1.2, p<.001) and proof (Odds=11.5, d=1.3, p<.001).

Results suggest that dynamic gestures may be associated with reasoning deductively about generalizable properties of space and shape and that pedagogical hints related to the directed actions are beneficial for insight and learning geometric proof.

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