Influencing Mindsets and Motivation in Procedural Skills Learning: Two Randomized Studies

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OBJECTIVES: An incremental (growth) theory of intelligence (mindset), compared with an entity (fixed) mindset, has been associated with improved motivation and performance. Interventions to induce incremental beliefs have improved performance on non-surgical motor tasks. We sought to evaluate the impact of 2 brief interventions to induce incremental beliefs in the context of learning a surgical task.

DESIGN: Two randomized experiments.

PARTICIPANTS AND SETTING: Secondary school students participating in medical simulation-based training activities at an academic medical center.

INTERVENTIONS: We created 4 instructional messages intended to influence mindsets (two 60-second videos in Study 1, 2 fabricated "journal articles" in Study 2). In each study, one message emphasized that ability improves with practice (incremental); the other emphasized that ability is fixed (entity). After reviewing their randomly-assigned message, participants completed a laparoscopic cutting task as many times as they desired. Measurements included performance (product quality, self-reported task, and completion time), task persistence (repetitions), and entity beliefs.

RESULTS: Two hundred and three students completed Study 1. Postevent entity beliefs (1 = lowest, 6 = highest) were similar between groups (incremental, 2.0 vs entity, 2.0; $p = 0.78$). Contrary to hypothesis, the incremental video group demonstrated slower time (276 vs 191 seconds; $p < 0.0001$), lower product quality (7.2 vs 3.8 mm deviation; $p < 0.0001$), and fewer task repetitions (1.4 vs 1.8; $p = 0.02$). In Study 2, 113 participants provided outcomes related to mindset beliefs, but only 14 provided usable performance outcomes. Postevent entity beliefs were lower in the incremental article group (1.7 vs 2.4; $p < 0.0001$). Task time (507 vs 585 seconds; $p = 0.40$) and quality (7.1 vs 7.5 mm deviation; $p = 0.85$) were similar between groups.

CONCLUSIONS: Brief motivational interventions can influence procedural performance and motivation. We need to better understand motivation and other affective influences on procedural skills learning. Mindset theory shows promise in this regard. (J Surg Ed 76:652–663. © 2018 Association of Program Directors in Surgery. Published by Elsevier Inc. All rights reserved.)

KEY WORDS: Motivation, personal differences, Simulation Training, achievement goals

COMPETENCIES: Patient Care

INTRODUCTION

Master surgeons are not born talented and gifted; they are created with deliberate practice, feedback, and drive. However, an exclusive focus on clinical skill and technical ability may overlook the power of motivation and emotions in learning.[1-3] Indeed, a well-timed compliment or challenge may ignite passion, sustained effort, and self-directed learning. Although surgeon educators recognize wide variation in the motivation of the trainees they supervise, few

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studies have empirically investigated motivation in procedural skills learning.[4-6] As we seek to optimize surgery training for medical students and residents, we should examine more carefully how to favorably influence motivation.

Dweck's theory of "implicit theories of intelligence" proposes that people possess subconscious beliefs (implicit self-theories or mindsets) about intelligence, ability, and the capacity to learn and change, and that these beliefs influence achievement goals which in turn influence learning and performance.[1,7-9] Some people, the theory proposes, believe that intelligence and ability are static, stable traits (a fixed or "entity" mindset or implicit theory). Others believe that intelligence and ability can increase or improve through learning (a growth or "incremental" mindset/theory). Those with entity mindsets tend to set performance-oriented achievement goals (focusing on doing better than others and avoiding the appearance of incompetence), attribute failure to low ability, and adopt "helpless" strategies (e.g., withdrawal of effort) in the face of challenge or failure. By contrast, those with incremental mindsets tend to set mastery-oriented achievement goals (focusing on the acquisition of increased knowledge and skills), attribute failure to low effort, and adopt "mastery" strategies (e.g., increased effort, change in strategy) in the face of setbacks. A 2013 meta-analysis of 85 studies found that incremental mindsets are associated with mastery-oriented processes and goal achievement.[10]

Evidence in K-12 and undergraduate college education suggests that simple interventions to induce an incremental mindset can enhance motivation, influence instructional choices, and improve short- and long-term learning outcomes including test performance, grade point average, and rates of college enrollment and dropout.[11-19] Successful interventions have included brief video clips,[11,12] fabricated "journal" articles,[13,14] verbal instructions,[15] verbal praise,[16] short online modules,[17,18] writing activities,[11] one-on-one mentoring,[19] and multisession workshops.[14] Researchers have extended these findings to motor skills learning,[20] showing that brief incremental-oriented verbal instructions (as short as 2 sentences) can lead to short-term (same-day or next-day) improvements in tasks such as dribbling a soccer ball, throwing a beanbag, or balancing.[21-23]

The brevity of some of these interventions, and their often large effects, suggest a potentially powerful role in enhancing health professions education for both cognitive and motor skills.[1,9] However, we are not aware of any studies in a health professions context attempting to directly influence learners' mindsets. Moreover, not all mindset interventions have been successful.[24,25] These gaps suggest the need for further study of mindsets in the context of surgical education.

We hypothesized that brief interventions intended to induce an incremental mindset would improve performance on a surgery procedural task (less time and better quality) and increase motivation, compared with interventions intended to induce or maintain an entity mindset. We report 2 studies addressing this hypothesis. Study 1 used short motivational video clips while Study 2 used fabricated essays formatted to look like journal articles.

METHODS

We conducted 2 cluster-randomized studies comparing motivational interventions intended to influence participants' mindsets. We did this in the context of a half-day medical simulation-based activity organized to promote interest in medicine among local youth, held at an academic medical center. All participants were secondary school students. Students were assigned to groups of up to 10 students, and rotated among 7 stations with hands-on simulation-based training in cardiopulmonary resuscitation, suturing, laparoscopic cutting, blood vessel ligation, and abdominal ultrasound. Our Institutional Review Board deemed both studies Exempt. All participants and the parents of those under 18 gave consent.

These studies took place during the laparoscopic cutting station. Each student worked alone to complete a "precision cutting task" modified from the Fundamentals of Laparoscopic Surgery training program.[26] They were instructed to complete this task as often as they desired during the allotted time (approximately 18 minutes).

Study 1

Study 1 took place in October 2016. Students were organized into groups by school, with large schools split into multiple groups. Groups were randomly assigned to intervention format using the Excel randomization function. The surgical task required students to use laparoscopic instruments to cut a half-circle marked with pen on a 2-inch-square gauze.

Interventions and Independent Variable

The independent variable for this study was "mindset emphasis," with 2 conditions: Incremental video and Entity video. We created two 60-second motivational videos comprised of still images and on-screen text with voiceover narration by a research assistant. The "Incremental" video was intended to induce an incremental mindset by emphasizing the capacity to learn, telling students that, "It's actually entirely normal to struggle with this task at first before you start to improve. Fortunately, the brain has a remarkable ability to learn and adapt; almost everyone can master this task if they work at it. The more you practice, the better you'll get. So keep a positive mindset and get practicing."

The "Entity" video was intended to induce a neutral or entity-oriented mindset by emphasizing the difficulty of the task, telling students that, "This task is harder than it looks. . . . Some people seem to overcome these barriers with ease ... This is a really important task for all surgeons to learn. Do you have what it takes to be a world-class surgeon? Do your best . . . and find out!" Appendix 1 contains a transcript of both videos. All students in a given group watched the same video immediately upon arrival at the station.

Instruments and Outcomes

The primary outcomes for this study were the product quality (of each cut half-circle) and time required to complete each task repetition. Product quality was determined by collecting each piece of cut gauze and measuring the largest deviation from the marked outline, in millimeters. Each student timed each task completion using a stopwatch, and wrote that time on the cut piece of gauze (i.e., self-reported time).

Secondary outcomes included task persistence (an objective measure of motivation[27]), and self-report measures of entity mindset, motivation, mental effort, workload, and aptitude for surgery.

- We measured task persistence as the number of repetitions completed (i.e., by counting pieces of gauze submitted).
- We measured incremental/entity mindset at the start and end of the half-day event using the Implicit Theories of Intelligence Scale (ITIS).[7,28,29] This instrument contains 4 incremental items and 4 entity items, each with 6 bipolar response options (1 = strongly disagree, 6 = strongly agree). For postevent measurement, we used only the entity items (following the suggestion by Dweck[7] that this subscale is sufficient for repeated measurements). Factor analyses generally support the proposed structure of this instrument's scores,[30,31] and prior work suggests high internal consistency.[30-32] The internal consistency reliabilities (Cronbach's alpha) of baseline incremental and entity scores in our sample were 0.79 and 0.78, respectively. We have separately reported more detailed validity evidence for ITIS scores.[29]
- We measured perceived mental effort at the end of each task using the statement proposed by Paas:[33] "In the task I just completed, I invested ___ mental effort." There were 9 bipolar response options (1 = very very low, 9 = very very high).
- We measured perceived motivation at the end of each task using the statement, "My motivation to try this task again is __." Response options were identical to the mental effort statement.
- We measured perceived workload at the end of the station using 2 items from the NASA-TLX (level of work and discouragement).[34] Response options ranged from 0 (very low) to 20 (very high).
- Finally, to measure aptitude for surgery, at the end of the half-day event students indicated agreement with a statement, "I have what it takes to be a skilled surgeon," using 6 bipolar response options (1 = strongly disagree, 6 = strongly agree).

All measurements were obtained using paper forms except those measured from or written on the gauze. Data were entered into an electronic database in duplicate, and errors corrected.

Statistical Analysis

Of >300 datapoints available, we excluded 6 outliers (1 time, 5 quality) that were >3 standard deviations (SDs) above the mean. We compared all outcomes between groups with hierarchical linear models using mixed models analysis of variance, accounting for the clustered randomization and, as appropriate, for repeated measures on students (i.e., for task time, circle quality, mental effort, and motivation). To account for possible between-group differences attributable to school, we adjusted for school in all analyses. We used ranked data (i.e., a nonparametric approach) when analyzing the number of task repetitions. In a sensitivity analysis, we repeated all analyses using ranked data and found essentially identical results with one exception (noted in results). We also examined for order effects (i.e., differences arising from the sequence of station completion) for time and quality outcomes.

We compared student demographics using the *t* test or chi-squared test, as appropriate. We calculated Cohen's d using the pooled SD; for measures with multiple time points we used the SD from baseline or first repetition scores.

The analyst was blinded to the intervention until main analyses were finalized. All participants were analyzed in the groups to which they were originally assigned (intention to treat), using a 2-sided alpha level of 0.05 for tests of statistical significance. We used SAS 9.4 (SAS Institute Inc., Cary, North Carolina) for all analyses.

Study 2

Study 2 took place in May 2017, and used a different group of secondary school students, a different intervention, and slightly different measurements. The surgical task required students to use laparoscopic instruments to cut a curved 3-inch line marked on heavy paper.

Students were randomly assigned as individuals to groups using the Excel randomization function, with

stratification by school. Groups were then randomly assigned to an intervention (article format), and rotated together to minimize the chance of students viewing the unassigned article. One school of 19 students arrived off-schedule, and these students were assigned to groups by alternating students rather than using Excel; none of these students contributed data to the learning outcomes.

Interventions

The independent variable for this study was "mindset emphasis," with 2 conditions: Incremental article and Entity article. We created 2 one-page essays entitled "Natural Talent or Learnable Skill: Can Children's Aptitudes Change?" and formatted to look like informational articles published in the "News You Can Use" section of a (fictitious) trade journal, "Teaching Psychology Today." We used as models 2 fictitious articles used in previous mindsets research.[35] Each article synopsized the fabricated research findings of 4 psychology scientists, but the "findings" presented were systematically varied to reflect either an incremental mindset (e.g., "Environmental factors and intense willpower appear to profoundly influence skill ability") or an entity mindset ("Neither environmental factors nor intense willpower appear to influence skill ability"); see Appendix 3 for the full text of each article. After reading the article, we asked students to summarize in their own words the main point and evidence used, and appraise the article's credibility using a 10-option response scale (1 = "not credible at all", 10 = "very credible"). At the end of the event (after data collection was complete) we gave each participant a paper explaining that the articles were entirely fabricated.

Instruments and Outcomes

Product quality, task completion time, task persistence, and self-reported motivation, mental effort, and aptitude for surgery were measured as in Study 1. We did not measure workload in Study 2. We measured entity/incremental mindset using a shortened 4-item version of the ITIS,[36] retaining the 2 items from each domain with the highest inter-item correlation on Study 1 scores. We measured mindset at the start (baseline) and end of the half-day event. The internal consistency (Cronbach's alpha) for baseline entity and incremental scores was 0.81 and 0.80, respectively. We also measured entity mindset at the start of the station to assess the effectiveness of the intervention (a manipulation check) using one (the first) entity item.

Statistical Analysis

Since randomization was individual we did not need to account for clustering and hence compared outcomes between groups using the t-test for most analyses. We used the Wilcoxon rank sum test to compare task repetitions, and general linear models to compare mindset beliefs adjusting for baseline scores. We analyzed task-specific outcomes (time, quality, motivation, and mental effort) for the first task only, and we did not adjust for school. We analyzed groups according to the assigned intervention, but excluded those who did not actually read either article. The analysis approach was otherwise similar to that of Study 1, including the conduct of non-parametric sensitivity analyses.

RESULTS

Study 1

Two hundred and three students participated in the laparoscopic cutting station, with 86 viewing the Incremental video and 117 viewing the Entity video. The 10 participating schools contributed 3 to 57 students each (median 6). There were no statistically significant differences between groups in gender, grade, age, or baseline entity or incremental beliefs (Table 1).

Primary Outcomes

Those viewing the Entity video demonstrated statistically significantly better performance in both time and product quality than those viewing the Incremental video (see Table 2). Specifically, the Incremental group performed the task more slowly (276 vs 191 seconds; difference [95% confidence interval], 86 [60, 111]; $p < 0.0001$) and had greater deviation from the marked outline (7.2 vs 3.8 mm of deviation; difference, 3.5 [2.4, 4.6]; $p < 0.0001$). The magnitude of difference (effect size) approached a moderate size (Cohen's d, 0.49) for time and was large (Cohen's d, 0.84) for quality.

Both time and quality varied by station order ($p < 0.02$) although there was no consistent pattern or trend in this variation. However, we found a significant intervention-by-order interaction for time outcomes ($p_{interaction} = 0.0006$) suggesting that Incremental times were longer later in the day, and Entity times were shorter (see Appendix 2 for more detailed information). The intervention-by-order interaction for quality outcomes was not statistically significant ($p_{interaction} = 0.29$).

Secondary Outcomes

One hundred fourteen (56%), 61 (30%), 22 (11%), 4 (5%), and 1 (0.5%) participants completed 1, 2, 3, 4, or 5 task repetitions, respectively. The number of repetitions — an objective measure of motivation (task persistence) — was statistically significantly lower for those watching

TABLE 1. Participant Demographic Characteristics

Domain	Characteristic	Incremental Group	Entity Group	p
Study 1, completed station		***N = 86***	***N = 117***	
Gender, no. (%)*	Male	22 (39%)	34 (61%)	0.62
	Female	62 (43%)	82 (57%)	
Grade, no. (%)*	12	28 (43%)	37 (57%)	0.24
	11	17 (38%)	28 (62%)	
	10	8 (30%)	19 (70%)	
	9	5 (83%)	1 (17%)	
	8	12 (43%)	16 (57%)	
	7	14 (48%)	15 (52%)	
Age, mean (SD)*	Years	15.3 (2.0)	15.4 (1.9)	0.62
Entity beliefs, pre-event, mean (SD)†,‡	–	2.4 (0.9)	2.4 (0.9)	0.83
Incremental beliefs, pre-event, mean (SD)†,‡	–	4.7 (0.8)	4.7 (0.8)	0.55
Study 2, received intervention		***N = 60***	***N = 59***	
Gender, no. (%)	Male	24 (62%)	15 (38%)	0.09
	Female	36 (45%)	44 (55%)	
Grade, no. (%)	12	35 (51%)	34 (49%)	0.44
	11	16 (43%)	21 (57%)	
	10	2 (50%)	2 (50%)	
	9	6 (75%)	2 (25%)	
Age, mean (SD)	Years	17.2 (1.1)	17.2 (0.9)	0.70
Entity beliefs, pre-event, mean (SD)†,‡	–	2.3 (0.9)	2.2 (0.9)	0.64
Incremental beliefs, pre-event, mean (SD)†	–	4.5 (0.9)	4.9 (0.8)	0.03
Study 2, completed task		***N = 8***	***N = 6***	
Gender, no. (%)	Male	5 (83%)	1 (17%)	0.09
	Female	3 (38%)	5 (62%)	
Grade, no. (%)	12	4 (67%)	2 (33%)	0.82
	11	3 (50%)	3 (50%)	
	10	1 (50%)	1 (50%)	
Age, mean (SD)	Years	17.4 (0.7)	16.5 (1.0)	0.09
Entity beliefs, pre-event, mean (SD)†,‡	–	2.0 (0.7)	2.7 (1.3)	0.28
Incremental beliefs, pre-event, mean (SD)†	–	4.4 (0.8)	5.0 (0.5)	0.16

*Gender, grade, and age missing for 3 students.
†1 = strongly disagree, 6 = strongly agree.
‡Incremental/entity beliefs missing for 9 students.

the Incremental video (difference, −0.5 [−0.8, −0.1] repetitions; p = 0.02), reflecting a moderate effect (Cohen's d = −0.57). Self-reported motivation to complete another repetition was similar between groups (difference on a 9-point response scale, 0.3 [−0.2, 0.9], p = 0.24), whereas perceived mental effort was higher for the Incremental video (difference, 0.5 [0.0, 0.9]; p = 0.04). Of note, the statistical significance of the difference in mental effort did not persist when re-analyzed using nonparametric methods (p = 0.29). Post-station NASA-TLX ratings of level of work and discouragement were similar between groups (p ≥ 0.11; see Table 2).

On the postevent (end-of-day) survey, between-group differences in entity beliefs and aptitude for surgery were small or negligible in magnitude, and not statistically significant (Table 2).

Study 2

Two hundred sixteen students were randomly assigned to groups prior to the event; of these, 37 did not attend and 60 did not arrive in time to read the article prior to starting their first station (i.e., did not receive the intervention). Baseline entity and incremental beliefs were similar among attendees who did vs did not read the article (p > 0.19, data not shown). Of the 119 who received the mindset intervention, 105 had their performance during the cutting station interrupted (e.g., by logistical difficulties with station operations, or by an enthusiastic surgeon-educator who engaged students in one-on-one teaching) leaving only 14 who completed the task at least once with usable performance data (product quality, task persistence). One-hundred thirteen students had usable post-intervention mindset scores. Figure 1 illustrates the participant flow. Baseline incremental beliefs were higher in the Entity group (p = 0.03; see Table 1). There were no other statistically significant differences in group demographics among the 119 who received the intervention or the 14 who completed the task. The 11 participating schools contributed one to 39 students each (median 5) to the 119 intervention recipients.

TABLE 2. Study 1: Comparison of Incremental vs Entity Video

Outcome	Incremental Video Mean (SEM)* N = 86	Entity Video Mean (SEM)* N = 117	Difference Mean (95% CI)*	p	Effect size (Cohen's d)
Time (seconds; per repetition)	276 (13)	191 (7)	86 (60, 111)	<0.0001	0.49
Quality (mm of deviation [lower is better]; per repetition)	7.2 (0.7)	3.8 (0.5)	3.5 (2.4, 4.6)	<0.0001	0.84
Task persistence (no. of repetitions)	1.4 (0.1)	1.8 (0.1)	−0.5 (-0.8, −0.1)	0.02	−0.57
Motivation to do another (9 = highest; after each repetition)	7.5 (0.3)	7.2 (0.2)	0.3 (−0.2, 0.9)	0.24	0.22
Mental effort (9 = highest; after each repetition)	7.4 (0.2)	6.9 (0.2)	0.5 (0.0, 0.9)	0.04†	0.39
NASA-TLX: Level of work (20 = highest; post-station)‡	17.5 (0.6)	16.5 (0.5)	1.0 (−0.3, 2.4)	0.11	0.27
NASA-TLX: Discouragement (20 = highest; post-station)‡	11.5 (0.9)	10.5 (0.8)	1.1 (−0.9, 3.0)	0.26	0.11
Entity beliefs (6 = highest; postevent [end of day])§	2.0 (0.1)	2.0 (0.1)	−0.04 (−0.3, 0.3)	0.78	−0.04
Aptitude for surgery (6 = highest; postevent [end of day])‖	4.1 (0.2)	3.9 (0.2)	0.2 (−0.2, 0.6)	0.35	0.19

*Difference = Incremental - Entity. SEM = standard error of the mean; CI = confidence interval. We report SEM instead of standard deviation because the mixed effects analysis of variance used to analyze most outcomes does not yield a standard deviation.
†The sensitivity analysis using a nonparametric approach did not reach statistical significance (p = 0.29) for this outcome.
‡Level of work = "How hard did you have to work to accomplish your level of performance?" Discouragement = "How insecure, discouraged, irritated, stressed, and annoyed were you?"
§Entity beliefs were measured at the very start and end of the half-day event. Postevent entity beliefs were adjusted for baseline scores.
‖Aptitude for surgery = "I have what it takes to be a skilled surgeon."

Manipulation Check

We found statistically significant differences in entity beliefs following the intervention, with those reading the Incremental article showing a decrease of -0.4 (95% confidence interval, −0.6, −0.1; p = 0.004; Cohen's d, −0.42) and those reading the Entity article showing an increase of 0.5 (0.2, 0.8; p = 0.0006; Cohen's d, 0.58). The between-group difference in postintervention entity beliefs (adjusted for baseline scores) was statistically significant (difference, −0.9 [−1.3, −0.6]; p < 0.0001). We found no difference in the perceived credibility of the Entity and Incremental articles (p = 0.24) (see Table 3 for details).

Primary Outcomes

Among the 14 students who completed the cutting task, those reading the Incremental article were slightly faster than the Entity group (difference, −77 seconds [−271, 116]; p = 0.40), which represents an effect of near-moderate magnitude (Cohen's d, −0.46) but is not statistically significant. Similarly, product quality slightly favored the Incremental article (−0.4 [−4.8, 4.0]; p = 0.85), but was negligible in magnitude (Cohen's d, −0.11) and not statistically significant. Only 2 students (one in each group) completed a second task repetition.

Secondary Outcomes

Among the 14 students who completed the task, motivation to complete another task was somewhat higher (Cohen's d, 0.53) and perceived mental effort somewhat lower (Cohen's d, −0.47) for those receiving the Incremental intervention, but these differences were not statistically significant (p ≥ 0.18; see Table 3).

Among the 109 students who received the study interventions and completed the postevent (end-of-day) survey, the Incremental group demonstrated a statistically significant net decrease in entity beliefs from baseline to postevent (−0.6 [−0.8, −0.4]; p < 0.0001; Cohen's d, −0.69) and an increase in incremental scores (0.5 [0.3, 0.7]; p < 0.0001; Cohen's d, 0.61); see Fig. 2. The Entity group demonstrated only small net changes in entity beliefs (0.1 [−0.1, 0.3]; p = 0.46; Cohen's d, 0.09) or incremental beliefs (−0.2 [−0.4, 0.03]; p = 0.09; Cohen's d, −0.20). The between-group differences in both entity and incremental beliefs postevent (adjusted for baseline scores) were moderate in magnitude (Cohen's d, 0.68) and statistically significant (p ≤ 0.002; see Table 3). The difference in aptitude for surgery was negligible in magnitude and not statistically significant.

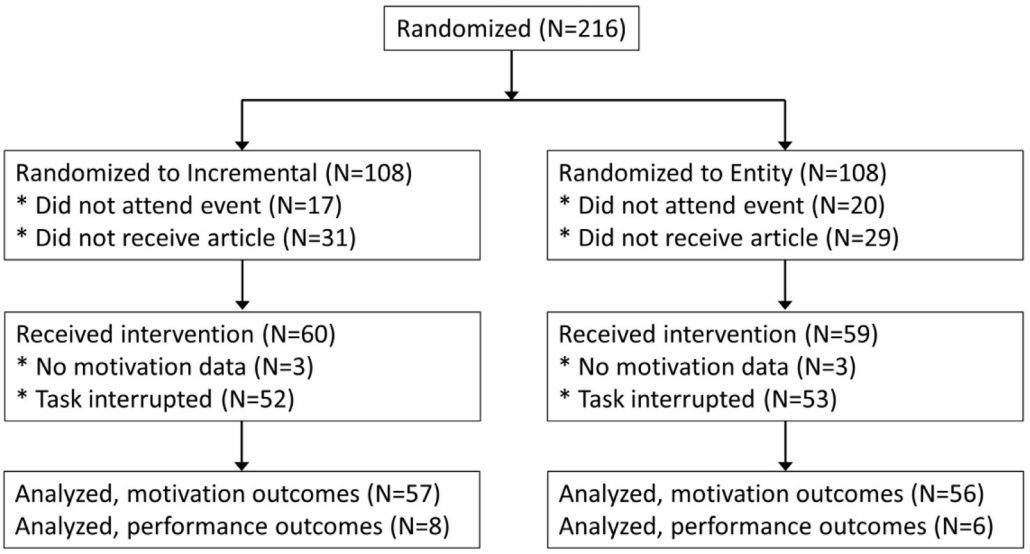

FIGURE 1. Flow of participants in Study 2.

DISCUSSION

These studies are the first to explore the impact of mindset interventions on a surgical task. Contrary to our hypothesis, the video intended to induce an entity mindset in Study 1 was associated with statistically significant and educationally meaningful improvements in performance (faster task completion and better-quality products) and greater task persistence (number of repetitions) compared with the video intended to induce an incremental mindset. We also found no difference in postevent entity scores. There was a small but statistically significant increase in reported mental effort for the Incremental video, but no difference in motivation to perform another repetition. We found an intervention-by-order interaction for time outcomes, suggesting that the separation between Incremental and Entity groups was greater when the station was completed later in the day. Of note, participants in both groups found the task to be quite difficult (high scores for mental effort and NASA-TLX level of work).

Although Study 2 was limited by large attrition and suboptimal power, the findings generally aligned with our hypotheses. The intervention (reading and summarizing one-page articles) was successful in inducing moderately large, statistically significant changes in mindsets according to our intention. The Incremental article seemed to be associated with educationally meaningful improvements in speed, task motivation, and mental effort, but these differences did not reach statistical significance. Several findings suggest that the central message of the entity article contradicted students' inherent beliefs: the entity article was viewed as somewhat (but not statistically significantly) less credible; entity beliefs were less strongly endorsed than incremental beliefs at all-time points, and the initial rise in entity beliefs immediately post-intervention did not persist to the end of the multi-station event. Task difficulty (mental effort) was again rather high.

LIMITATIONS AND STRENGTHS

Although these studies were conducted in the context of a surgical task, the sample (secondary school students) may limit the generalizability to health professions learners. We nonetheless believe our findings have relevance to surgery residents and medical students, as these studies set the stage for future investigations of motivation in learning procedural skills. It is possible that entity-oriented students, being more concerned about appearances than incremental-oriented students, systematically misrepresented their self-reported task times; however, product quality was objectively determined. The method of intervention assignment in Study 1 randomized participants in clusters by school, and it is possible that unmeasured differences between schools could account in-part for the observed differences; however, we accounted for clustering and school in all Study 1 analyses. We improved the randomization process in Study 2, but the small final sample size limited our statistical power. High attrition in Study 2 also introduced the possibility of bias, although attrition resulted almost entirely from logistical challenges rather than student decisions or motivations, and should have affected both groups equally. Students worked at adjacent task

TABLE 3. Study 2: Comparison of Incremental vs Entity Article

Outcome	No. Responses Incremental, Entity	Incremental Mean (SEM)*	Entity Mean (SEM)*	Difference Mean (95% CI)*	p	Effect Size (Cohen's d)
Manipulation check: Entity beliefs (6 = highest; postintervention)†	57, 56	1.9 (0.1)	2.9 (0.1)	−0.9 (−1.3, −0.6)	<0.0001	−0.78
Manipulation check: Credibility of article (10 = highest; postintervention)	20, 17	7.4 (0.3)	6.9 (0.4)	0.5 (−0.4, 1.4)	0.24	0.39
Time (seconds; per repetition)	8, 6	507 (67)	585 (59)	−77 (−271, 116)	0.40	−0.46
Quality (mm of deviation [lower is better]; per repetition)	8, 6	7.1 (1.3)	7.5 (1.5)	−0.4 (−4.8, 4.0)	0.85	−0.11
Task persistence (no. of repetitions)	8, 6	1.1 (0.1)	1.2 (0.2)	−0.04 (−0.5, 0.4)	0.81	−0.11
Motivation to do another (9 = highest; after each repetition)	8, 6	8.0 (0.3)	6.8 (0.7)	1.2 (−0.7, 3.0)	0.18	0.53
Mental effort (9 = highest; after each repetition)	8, 6	7.3 (0.8)	8.0 (0.4)	−0.7 (−2.7, 1.2)	0.40	−0.47
Entity beliefs (6 = highest; postevent [end of day])†	54, 55	1.7 (0.1)	2.4 (0.1)	−0.7 (−1.0, −0.4)	<0.0001	−0.68
Incremental beliefs (6 = highest; postevent [end of day])†	54, 55	5.2 (0.1)	4.6 (0.1)	0.6 (0.3, 0.9)	0.002	0.68
Aptitude for surgery (6 = highest; postevent [end of day])‡	54, 55	3.5 (0.2)	3.7 (0.2)	−0.2 (−0.8, 0.3)	0.37	−0.17

* Difference = Incremental - Entity. SEM = standard error of the mean; CI = confidence interval.
† Entity and incremental beliefs were measured at the very start and end of the half-day event; entity beliefs were also measured just before starting the station (after reading the article). Postintervention and postevent analyses were adjusted for baseline scores.
‡ Aptitude for surgery = "I have what it takes to be a skilled surgeon."

trainers, and could have influenced one another's practice patterns; however, all students in a given group received the same intervention and thus were likely similarly motivated. We did not measure participants' interest in this task, which might have independently influenced their motivation to engage and learn;[37,38] however, baseline characteristics (including interest and other motives) should have been distributed evenly across interventions through randomization. All outcomes were measured in the context of training, yet some benefits of incremental beliefs may not become apparent until after a delay or transfer to new context. We found a small but statistically significant between-group difference in baseline incremental beliefs in Study 2, however all other measured participant characteristics were similar.

Strengths include ample power for Study 1, prespecified hypotheses (although the hypothesis was not confirmed in Study 1), and the measurement of outcomes reflecting performance (time and product quality), motivation, mental effort, and perceived aptitude.

ALTERNATIVE EXPLANATIONS: STUDY 1

We cannot be certain whether the unexpected findings in Study 1 reflect a true relationship between mindsets and procedural learning, or a flaw in intervention creation or premature assessment of study outcomes. It is possible that students with an incremental mindset might have worked more slowly and deliberately as part of a deep learning strategy, while those with an entity mindset worked more quickly and superficially. The Entity video might have also stimulated performance-oriented achievement goals (i.e., goals to do better than others), which can lead to improved performance-related outcomes, especially in the short-term.[39] If so, we might expect slow, deliberate students to demonstrate inferior proximate outcomes, with superior outcomes only manifesting after a delay or transfer to a new task. Opposing the latter proposition are 3 recent studies of achievement goals in surgical training, of which 2 favored mastery goals[4,5] and one found no significant difference.[6] Although we found no difference in postevent entity beliefs, which further undermines the argument that incremental/entity mindset was a mechanism for the between-group differences, this remains a possibility that could be further explored.

In a search for additional explanations, we carefully re-analyzed each video transcript. We speculate that the Entity video might have had the unintentional effect of encouraging self-challenging goals ("Do you have what it takes?"), relevance ("This is a really important task for all surgeons"), and general motivation ("Do your best!").

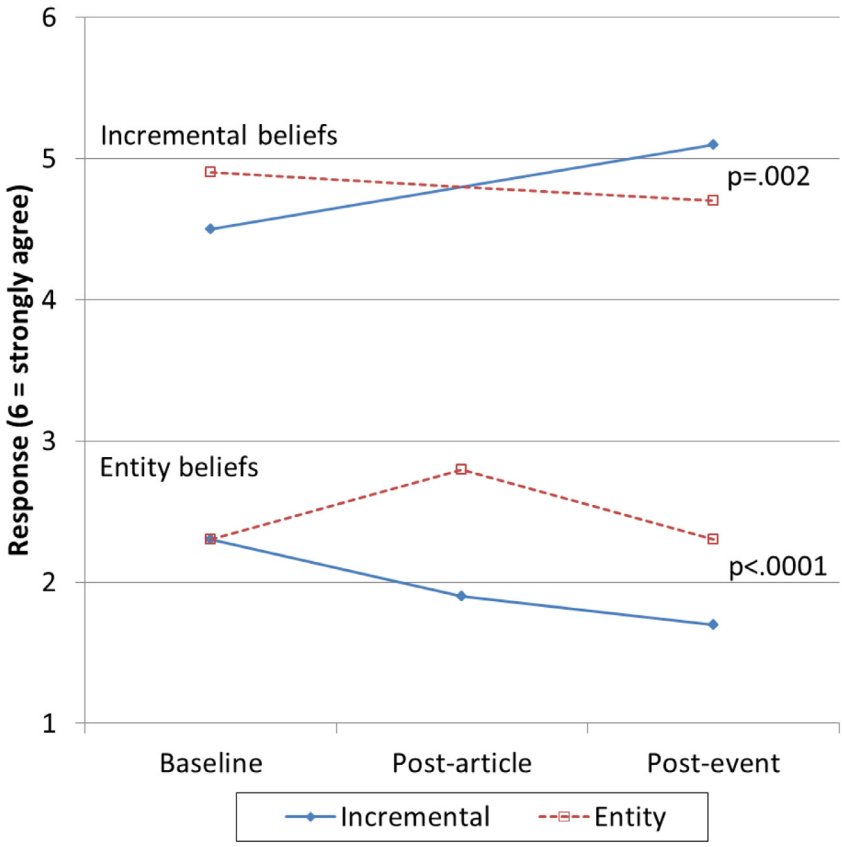

FIGURE. 2. Changes in mindset before and after reading an article to induce incremental vs entity beliefs (Study 2). Incremental beliefs were measured only at baseline and postevent (end of day). p values reflect comparison of postevent scores (N = 109), adjusted for baseline scores.

Such prompts might have been particularly salient in the context of this strictly-voluntary and highly-touted event, serving to magnify participants' already-high interest and autonomy. Interest and autonomy are key determinants of task persistence and learning success in other theories of motivation.[1,37,38] By contrast, the Incremental video may have unintentionally portrayed innate ability as important rather than unimportant ("You may wonder if you have the natural ability"), and the emphasis on practice ("get practicing" and the written text "practice practice practice") could have de-emphasized spontaneous interest. In short, our operationalization of the incremental/entity intervention might have stimulated unintended motives.

IMPLICATIONS

The inconsistent findings and collective limitations of these studies preclude drawing conclusions with direct implications for education practice. However, our findings highlight an important research theme that has received scant attention in health professions education to-date, and set the stage for future work in the field. Reading and summarizing one-page articles in Study 2 seemed to produce effects as intended, inducing differences in mindset and non-statistically-significant differences in performance that aligned with expectations. These findings support proof-of-concept for brief mindset interventions. This study should be replicated with adequate power, ideally using surgery residents or medical students and with tests of transfer and/or retention.

The 60-second videos in Study 1 also influenced learning and performance. Although the direction of effect conflicted with expectations, this again provides proof-of-concept that even very brief interventions can affect learning and performance. We need to better understand the cognitive and motivational processes at play, and how to predictably influence such processes to achieve desired long-term learning outcomes. We suggest further study of motivational videos, either modifying ours to better align with the intended construct, or using ours without modification and focusing on understanding the mechanism that led to observed differences. The addition of a generative element (i.e., probing

participants for comprehension or perceived implications) may be useful.

The intervention-by-order interaction in Study 1 suggests that student characteristics varied over the course of the day. Such changeable characteristics might include motivational beliefs (e.g., self-efficacy or mindsets) formulated based on performance in earlier stations, procedural skills transferred from earlier tasks, or fatigue. This finding highlights the importance of participant and contextual factors in both education practice and research.

Finally, these studies underscore the importance of motivation and other affective influences on procedural skills learning.[1,40-42] Neither video in Study 1 did anything to directly influence task-relevant knowledge or skill, yet we found a significant effect on performance. Authors have increasingly articulated the limitations of "cold cognition," and emphasized the central role of motivation and emotion in learning.[42-45] We need to better understand the interaction of cognition and motivation, with emphasis on the mechanisms and processes that underlie these interactions.

AUTHORSHIP

Authors DAC, BG, DRF, and NDN conceived the study; BG, DRF, NN, and FJCL acquired data; DAC, ML, and ARA planned the analysis; and DAC drafted the initial manuscript. All authors were involved in interpreting data and revising the manuscript, and all approved the final manuscript.

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COMPETING INTERESTS

We are not aware of any conflicts of interest.

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SUPPLEMENTARY INFORMATION

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