

# BMJ Open Investigation of divergent thinking among surgeons and surgeon trainees in Canada (IDEAS): a mixed-methods study

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## ABSTRACT

**Objective** To assess the creative potential of surgeons and surgeon trainees, as measured by divergent thinking. The secondary objectives were to identify factors associated with divergent thinking, assess confidence in creative problem-solving and the perceived effect of surgical training on creative potential, and explore the value of creativity in surgery.

**Design** We used a mixed-methods design, conducting a survey of divergent thinking ability using a validated questionnaire followed by two semi-structured interviews with top-scoring participants.

**Participants & setting** Surgeons and surgeon trainees in the Department of Surgery at McMaster University.

**Outcomes** The primary outcome was divergent thinking, assessed with the Abbreviated Torrance Test for Adults. Participants also self-assessed their confidence in creative problem-solving and the effect of surgical training on their creative potential. We performed descriptive analyses and multivariable linear regression to identify factors associated with divergent thinking. We conducted a thematic analysis of the interview responses.

**Results** 82 surgeons and surgeon trainees were surveyed; 43 were junior trainees and 28 were senior trainees. General surgery, orthopaedic surgery and plastic surgery represented 71.9% of the participants. The median participant age was 28 years (range 24–73), 51.2% of whom were female. Participants demonstrated levels of divergent thinking that were higher but not meaningfully different from the adult norm (62.39 (95% CI 61.25, 63.53),  $p < 0.001$ ). While participants scored significantly higher than the average adult on fluency (the ability to produce quantities of ideas) and flexibility (the ability to process information in different ways) ( $p < 0.001$  for both), they scored below average on originality (the ability to produce uncommon, new or unique ideas) ( $p < 0.001$ ). Regression analysis identified higher divergent thinking scores among females (estimated  $\beta = -3.58$  (95% CI  $-6.25$  to  $-0.90$ ),  $p = 0.010$ ).

**Conclusions** The divergent thinking ability among surgeons and surgeon trainees was not meaningfully different from the adult normative score; however, their ability to generate original ideas was below average.

## INTRODUCTION

During the Second World War, the USAir Force commissioned JP Guilford, a psychologist at

## STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ Used a validated measure of divergent thinking to measure the creative potential of surgeons and surgeon trainees.
- ⇒ Included participants from a range of surgical specialties and years of experience.
- ⇒ Performed semi-structured interviews with top-scoring participants to contextualise the results and provide insights in the importance of creativity in surgery.
- ⇒ Test results may have been influenced by motivational factors.

the University of Southern California, to help develop tests for the selection of pilots.<sup>1</sup> Aviation is a high-risk, safety-critical environment, and many of the processes are standardised in order to minimise the risk of error.<sup>2</sup> However, when unforeseen problems occur in life-critical situations, the ability to generate original, effective solutions when no prescribed procedure or solution is available—the ability to be creative—can save lives.<sup>3</sup> This is equally true for surgery as it is for aviation.

Surgery may not seem like a creative profession. Guidelines, evidence-based decision pathways and a training model characterised by demonstration and imitation are some of the ways that surgeons maximise safety by standardising the profession. This standardisation is antithetical to creativity, which involves risk-taking and experimentation.<sup>4</sup> Yet, creativity can be critical to the success and evolution of the surgical profession: consider the surgeon who finds a unique solution to stopping a haemorrhage or the development of a new, highly effective surgical technique. Despite the necessary standardisation of the profession, surgeons believe the ability to be creative is important and valuable.<sup>5–7</sup>

The process of creativity consists of two components: idea generation and



evaluation.<sup>8–10</sup> It was JP Guilford who first conceptualised the process of idea generation as divergent thinking.<sup>11</sup> Divergent thinking is therefore the cognitive starting point of creativity, with the evaluation or implementation of creative ideas happening downstream. Divergent thinking tests, like the Torrance Test of Creative Thinking (TTCT),<sup>12</sup> are the most widely used tests of creativity,<sup>13</sup> demonstrating a strong ability to predict creative achievement up to 40 years postadministration.<sup>14–16</sup> Divergent thinking can help measure the creative potential of surgeons.

To our knowledge, no studies of divergent thinking have been performed in the surgical population. We sought to fill this gap by conducting a survey of divergent thinking ability among surgeons and surgeon trainees. Given the above-average intellectual abilities of those who study medicine<sup>17 18</sup> and the association between general intelligence and divergent thinking,<sup>19</sup> we hypothesised that the divergent thinking ability of surgeons and surgeon trainees would be higher than the average adult.

### Objectives

To assess the creative potential of surgeons and surgeon trainees through the measurement of divergent thinking ability. As secondary objectives, we aimed to explore factors associated with divergent thinking, measure surgeons' confidence in creative problem-solving and the perceived effect of the surgical training on creative potential, and gain insights into the value of creativity in surgery.

### Methodology

For this mixed-methods study, we followed the strengthening the reporting of observational studies in epidemiology guideline for the reporting of our survey<sup>20</sup> and published our protocol.<sup>21</sup> The Hamilton Integrated Research Ethics Board provided approval for this research project (Project #15178). All participants provided informed consent by signing a written consent form.

### Patient and public involvement statement

The public/participants were not involved in the design, conduct, reporting or dissemination plans of the study.

### Study population

The target population was surgeons and surgeon trainees in the Department of Surgery at McMaster University. We used a convenience sampling method to recruit participants—we directly contacted staff surgeons and residents via email, as well as the programme director of the Surgical Foundations training programme (responsible for the training of new surgeon trainees). Recruitment took place between December 2022 and July 2023.

### Outcomes

We measured the primary outcome of divergent thinking ability using the Abbreviated Torrance Test for Adults (ATTA).<sup>22</sup> The ATTA is the abbreviated version of TTCT,<sup>23</sup> which is considered to be the best tool for

assessing creativity.<sup>24</sup> The TTCT has been found to be a valid predictor of creative and personal achievement up to 50 years after testing.<sup>14–16 25</sup> The ATTA test itself has been validated as a predictor of creative performance in an adult population.<sup>26</sup> It measures four norm-referenced abilities—fluency (the ability to produce quantities of ideas), originality (the ability to produce uncommon, new or unique ideas), elaboration (the ability to embellish ideas with details) and flexibility (the ability to process information in different ways; variety of ideas). The ATTA is a three-part test with both verbal and figural components: the first activity was a verbal task; activities 2 and 3 were figural (drawing) tasks. Each task was time-limited to 3 min.

We used the following statement to assess self-confidence in creative problem-solving, measured using a 7-point Likert scale (strongly disagree to strongly agree): 'I have confidence in my ability to solve problems creatively'. We also assessed the participant's belief that surgical training enhanced their creative potential using the following statement, measured on a 7-point Likert scale (strongly disagree to strongly agree): 'My work bolsters my creative potential'. All Likert responses were later converted into a 5-point scale (scores 2–3 and 5–6 were collapsed separately).

### Administration

Following consent, a baseline characteristics form was completed by each participant. Collected information included age, sex, years of postgraduate surgical experience, surgical specialty, relationship status, ethnicity, undergraduate degree, time spent alone per day, hours worked per week, creative hobbies, creative friends, holding of a leadership position, whether the participant regularly makes time to reflect or think and their total peer-reviewed publications. After completion, a study coordinator educated on the testing protocol administered the ATTA test in person to ensure proper adherence to protocol.

### Semi-structured interviews

After all tests were graded, we conducted two semi-structured interviews with two top-scoring participants, who consented to being interviewed after being given the details of the interview. Each interview was conducted on Zoom and lasted roughly 40 min, performed by a single interviewer with a graduate-level training in health research methodology. A semi-structured interview guide (online supplemental material) was used in both interviews, covering the following topics: (1) the definition of creativity, (2) the effect of medical/surgical training on creativity, (3) the value of creativity in surgery and (4) the importance of creative hobbies and friends.

A thematic analysis of the interview responses was performed by a single assessor. Data from the two interviews were transcribed verbatim manually, anonymised and coded using a grounded theory approach<sup>27</sup> to assign categories and meaning to the data, extract emergent

themes and synthesise a coherent storyline.<sup>28</sup> The data were processed and stored in Microsoft Word.

### Statistical analysis

To estimate the total ATTA score using a 95% CI, with a margin of error of two and the ATTA score's SD of 7.87,<sup>29</sup> we calculated the minimum sample size to be 60 participants. As such, we included 10 variables in our linear regression.<sup>30</sup>

Following the ATTA manual, we calculated a total ATTA score—the sum of each scaled subscore—for each participant, normalised to the average adult.<sup>29</sup> The average adult's normative total ATTA score is 60 (SD 7.87); each subscore has a normative subscore of 15 (range 11–19).<sup>29</sup> The ATTA has high interrater reliability and a Kuder-Richardson 21 (KR21) reliability coefficient of 0.90,<sup>29</sup> indicating high test reliability. All tests were assessed independently by one reviewer trained on the ATTA assessment tool. A second grader was trained on ATTA assessment to assess all tests independently, solely for the purposes of testing the reliability of the first reviewer's scores. We calculated an intraclass correlation coefficient (ICC) between the two graders using a two-way mixed model, testing for absolute agreement.

We performed descriptive analyses of participant demographics, as well as the total ATTA scores (reported as mean scores with corresponding 95% CIs) across all participants and by baseline factors. The scores for the total ATTA score were graphically displayed using forest plots, and the distributions were illustrated using violin plots created with SRPlot.<sup>31</sup> Minimally important differences (MIDs) were estimated for the total ATTA score by using half the SD as a threshold for MID, which we estimated to be four points<sup>32</sup>; scores greater than 64 and less than 56 were thus considered an important difference from the adult population average. We also conducted two-sided, one-sample t-tests for the total ATTA score and each subscore compared with adult population average.<sup>29</sup>

We performed a multivariable linear regression to explore factors associated with divergent thinking ability using the following 10 variables: age, years of surgical experience, sex, number of publications, the presence of creative hobbies, the presence of creative friends, surgical specialty (general surgery vs other), time spent alone per day, hours worked per week and confidence in creative problem-solving ability. We included sex a predictor variable, as existing literature suggests a difference in divergent thinking between males and females.<sup>33–38</sup> The remaining variables were chosen a priori on exploratory grounds to generate hypotheses for further testing. For the regression model, we evaluated model assumptions and goodness-of-fit through residual analysis. As a sensitivity analysis, we reperformed the regression analysis treating the surgical specialty as a random effect to account for potential clustering of scores among participants within specialties. All statistical analyses were performed using SPSS 28.0,<sup>39</sup> and all bar graphs and forest plots were built in Microsoft Excel.

## RESULTS

For the total ATTA scores, the ICC between the two reviewers was 0.92 (95% CI 0.88, 0.95) indicating excellent reliability.<sup>40</sup>

### Respondent characteristics

82 surgeons and surgeon trainees completed the survey. The median age was 28 (range 24–73). Surgical experience varied widely, with a median of 2 years (range 0–30) of experience. The sample was predominantly composed of general surgeons (n=34), orthopaedic surgeons (n=14) and plastic surgeons (n=11). A complete table of baseline demographics can be found in [table 1](#).

### Creative self-perception

While 61 (74.4%) participants had confidence in their ability to solve problems creatively, less than half (39/79, 49.4%) agreed that their work bolstered their creative potential ([figure 1](#)).

### Divergent thinking scores

The divergent thinking ability of participants was significantly higher than the average adult ( $p < 0.001$ ), with a mean score of 62.39 (95% CI 61.25, 63.53) ([figure 2](#)). However, the difference was not meaningfully different, as it did not cross the MID threshold of 64. Similarly, no meaningful differences from the average adult score were observed across all baseline factors ([figure 2](#)).

The participants scored significantly higher than the average adult in fluency (ability to produce quantities of ideas; 16.83 (95% CI 16.43, 17.22)) and flexibility (ability to process information in different ways; 16.41 (95% CI 16.00, 16.83)) ([eTable 1](#);  $p < 0.001$  for both). However, they scored significantly lower in originality than the average adult (the ability to produce uncommon, new or unique ideas; 13.73 (95% CI 13.29, 14.17)) ([eTable 1](#);  $p < 0.001$ ). Elaboration scores (the ability to embellish ideas with details; 15.41 (95% CI 14.92, 15.91)) were not significantly different from the population average ([eTable 1](#);  $p = 0.097$ ).

The distributions of the total ATTA scores and subscores are displayed with violin plots ([eFigure 1 and 2](#)), and the results of the t-tests are summarised in [eTable 2](#).

### Subgroup effects

Being male had a significant negative association with divergent thinking ability (estimated  $\beta = -3.58$  (95% CI  $-6.25$  to  $-0.90$ ),  $p < 0.001$ ). Having less than 2 years of surgical experience trended towards a positive association with divergent thinking (estimated  $\beta = 2.53$  (95% CI  $-0.41$ , 5.46),  $p = 0.090$ ). No other factors were associated with divergent thinking ([table 2](#)). The sensitivity analysis treating surgical specialty as a random effect yielded similar results ([eTable 3](#)).

### Semi-structured interviews

The two participants interviewed were both female, came from musical backgrounds and in the first 2 years of their surgical training. Surgeon 1 (S1)

**Table 1** Baseline characteristics

Baseline characteristics	n=82
Age (years)	28 (24–73)
Sex	
Male	40 (48.8%)
Female	42 (51.2%)
Surgical experience (years)	2 (0–30)
0 years of experience	16 (19.5%)
1–2 years of experience	27 (32.9%)
3–5 years of experience	28 (34.1%)
6 years of experience	11 (13.4%)
Specialty	
Cardiac surgery	4 (4.9%)
General surgery	34 (41.5%)
Neurosurgery	5 (6.1%)
Obstetrics and gynaecology	5 (6.1%)
Ophthalmology	1 (1.2%)
Orthopaedics	14 (17.1%)
Otolaryngology	3 (3.6%)
Plastic	11 (13.4%)
Urology	5 (6.1%)
Relationship status	
Married	26 (31.7%)
Single	53 (64.6%)
Not reported	3 (3.6%)
Number of children	
0	68 (82.9%)
1	5 (6.1%)
2	3 (3.6%)
3+	2 (2.4%)
Not reported	4 (4.8%)
Undergraduate degree	
Science	74 (90.2%)
Engineering	1 (1.2%)
Arts	1 (1.2%)
Other (unspecified)	6 (12.4%)
Time alone per day (hours)	3.85 (2.62)
Work per week (hours)	73.08 (16.01)
Has a creative hobby	44 (53.7%)
Has creative friend(s)	68 (82.9%)
Makes time regularly to think	49 (59.8%)
Holds leadership position	10 (12.2%)
# of publications	4 (0–80)
I have confidence in my ability to solve problems creatively (7-point Likert)	
Strongly disagree (1)	0 (0.0%)
Disagree (2–3)	5 (6.1%)

Continued

**Table 1** Continued

Baseline characteristics	n=82
Neutral (4)	16 (19.5%)
Agree (5–6)	58 (70.7%)
Strongly agree (7)	3 (3.7%)
My work bolsters my creative potential (7-point Likert) (n=79)	
Strongly disagree (1)	4 (5.1%)
Disagree (2–3)	15 (19.0%)
Neutral (4)	21 (26.6%)
Agree (5–6)	37 (46.8%)
Strongly agree (7)	2 (2.5%)

Data presented as mean (SD), median (range) or n (%).

specialised in neurosurgery and Surgeon 2 (S2) specialised in orthopaedics.

S1 commented on the adverse effect of medical school and residency training on creativity.

I think that side of me has been stifled as I have gone through medical school and residency. There is this sense in medical training about professionalism, and how you are supposed to toe the line and be like everybody else. There's this mould and you're supposed to fit into it. And I wanted to do well in medicine, so I felt like I would do what I was supposed to do and put myself in the box. (S1)

When discussing the value of creativity in surgery, both S1 and S2 mentioned problem-solving both inside and outside of the operating room.

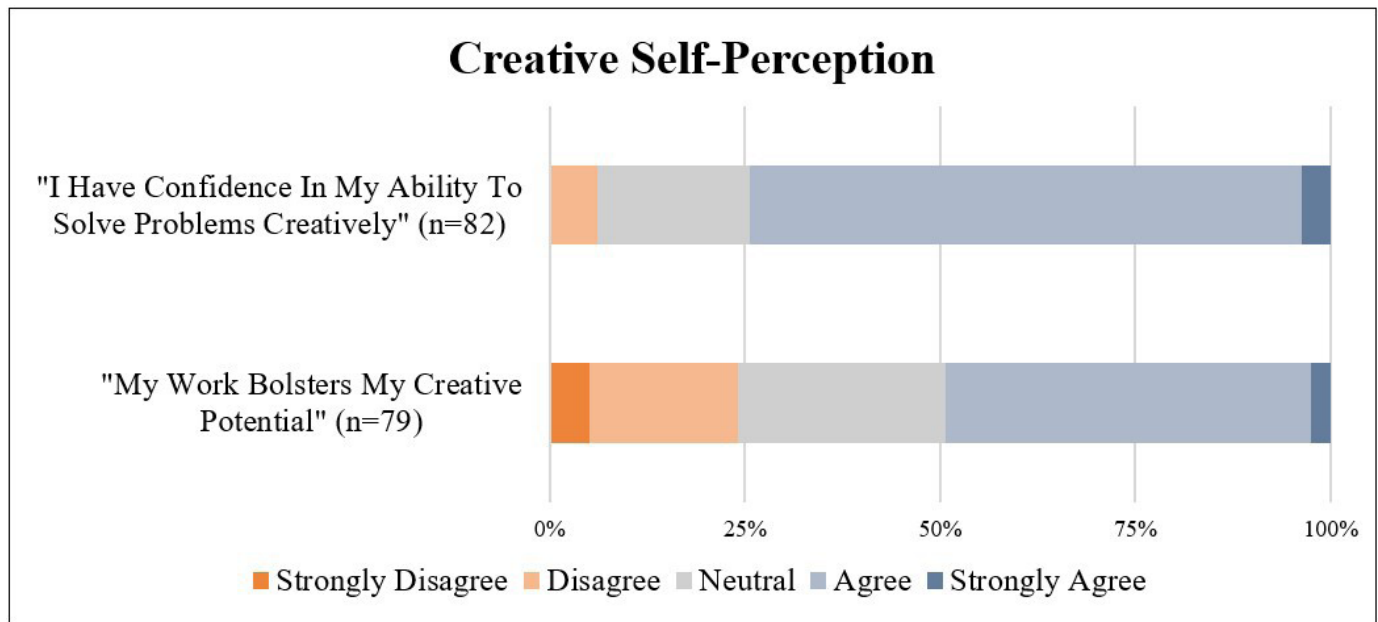
It's combination of technical mastery, but also flexible thinking relating to how surgery is different every time. No one can teach you how to perform every surgery. All you can do is build your skills and thinking [ability]. I don't think it's taught that way, but I think that's where the creativity in surgery comes out. (S1)

In the OR, troubleshooting things. I've been in cases where hardware removals were complicated because the instrument used wasn't available and you end up MacGyver'ing things. Even logistics – helping people navigate the healthcare system sometimes takes more creativity than you would think. (S2)

Both participants stressed the importance of developing creative problem-solving skills through exercising independent decision-making.

Having autonomy and being forced to problem-solve works those creative muscles, as far as creativity is related to problem-solving. (S1)

One thing that benefited me was overnight, when you run into issues, you're encouraged to figure it out. If there is a safety concern that is different, but there are a lot of little decisions you can make [that] you



**Figure 1** Likert responses for confidence in creative problem-solving and effect of surgical profession on creative potential.

can always fix in the morning. Being encouraged to make those decisions and figure those things out on my own as a first-year resident is helpful. (S2)

S1 also highlighted the impact that having imaginative individuals in one's life can have on one's creativity.

Being around people who are imaginative is a great way of keeping that [creativity] alive. (S1)

Both participants mentioned hobbies that allow one to engage their creativity as important outlets for surgeons.

It balances the 'non-playing' aspect of surgery because there's part of that which is important. I think it [creativity] can help with things like stress and burn-out. (S1)

I think it's important to have something outside of residency to sustain you. To have a whole life outside of medicine—it's easy to let that slip away, especially in the later years of medical school. (S2)

## DISCUSSION

While overall divergent thinking ability among surgeons and surgeon trainees was not meaningfully different from the adult population average, participants displayed significantly higher levels of fluency and flexibility but struggled to think originally. Females scored significantly higher on the test than males, and though not significant, having more surgical experience trended towards a negative association with divergent thinking. The semi-structured interviews with top-scoring participants supported several of the findings in the survey, with one interviewee suggesting her creativity was being 'stifled' by medical training.

We found only three studies on creativity in surgery: two citation analyses<sup>41 42</sup> and one cross-sectional study

including mostly non-physicians.<sup>43</sup> This makes our survey the first study of creativity in surgeons and surgeon trainees. We recruited over 80 participants, which exceeded the minimum sample size determined by our power calculation. Moreover, we collected sociodemographic and professional characteristics, enabling us to perform analyses to explore trends and identify factors associated with divergent thinking. We supported the survey with self-assessments of confidence in creative problem-solving and the impact of the surgical profession on creative potential. The qualitative component of our study helped to contextualise our results.

Our results are consistent with the results of several studies which have found females to significantly outperform males on creativity tests,<sup>33–38</sup> particularly as females reach higher education<sup>35 37</sup>; however, contrasting evidence finding no difference between males and females has also been reported.<sup>44–46</sup> Harnessing the creative potential of surgeons and surgeon trainees could benefit both surgeons and the patient they care for. Initiatives that address barriers to entry for females in surgery, such as mitigating gender discrimination,<sup>47 48</sup> and creating opportunities for participation in surgical innovation could be ways to do so.

Divergent thinking is correlated to broad retrieval ability and processing speed,<sup>19</sup> and more broadly, general intelligence.<sup>49 50</sup> Medical professionals are largely selected based on general intelligence, as measured by academic performance and standardised test scores.<sup>51 52</sup> This explains the high fluency and flexibility scores. But, given the high correlation between fluency, flexibility and originality,<sup>53–56</sup> we would expect to observe similarly high levels of originality. This was not the case and is a particularly important observation given the requirement of originality in creativity.<sup>57 58</sup> Finding significantly below-average levels of originality could be explained by the surgical

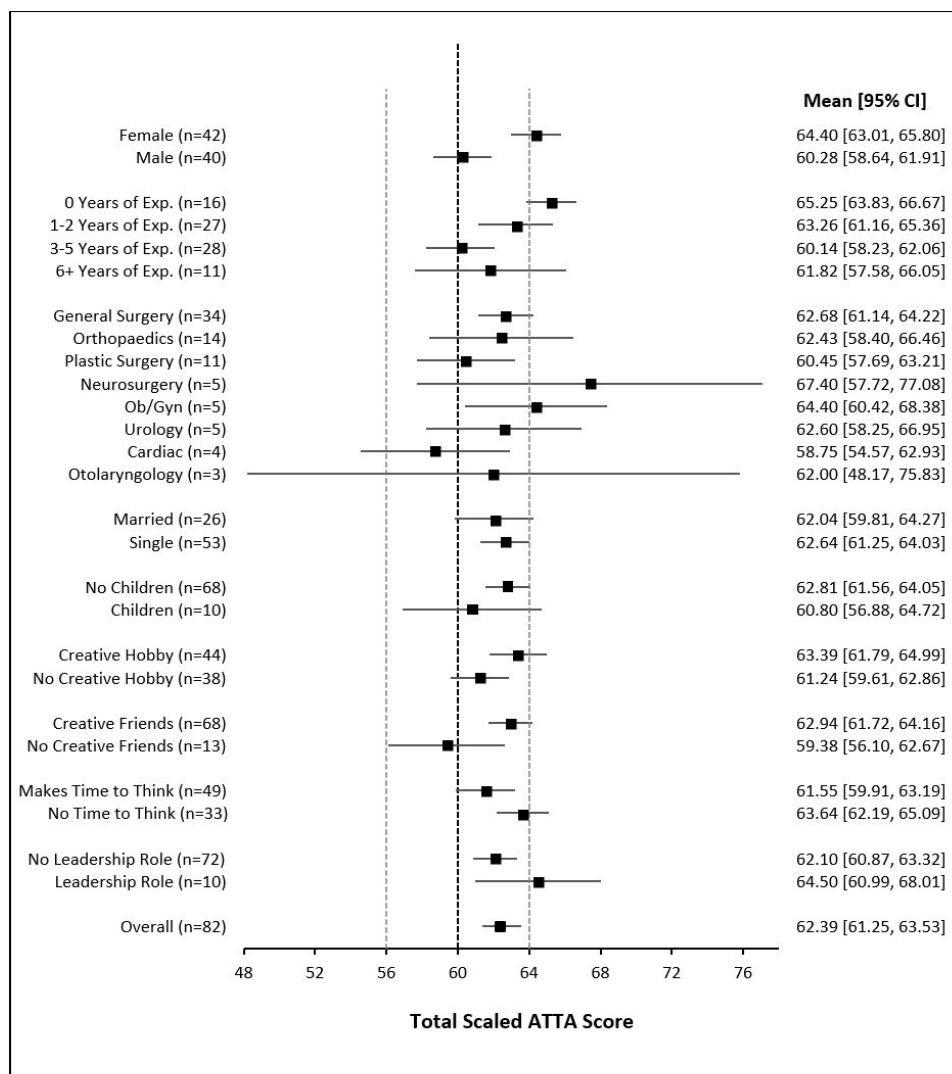


Figure 2

**Figure 2** Estimated total ATTA scores overall and by baseline factor. The adult normative score of 60, labelled with a black solid line. The estimated minimally important difference thresholds of 56 and 64 are labelled with grey dotted lines. ATTA, Abbreviated Torrance Test for Adults.

training process, as our regression results suggested. Given the risk and uncertainty inherent in the profession, the surgical training process, based on an apprenticeship model,<sup>39</sup> places a strong emphasis on following standards and instructions in the operating room. Particularly for novice trainees, creative ideas not steeped in the necessary domain expertise may feel too risky to suggest in the operating room. Moreover, the ability to generate original solutions decreases as one gains experience solving problems in a certain fashion.<sup>60</sup> Over time, the surgical training process could be leading to a lack of engagement in divergent thinking and original idea generation, as trainees inadvertently learn that, to become a 'good' surgeon, they must put their original ideas to the side and 'do as I do'. The negative impact of surgical training on divergent thinking was supported by our interviews, where a 'stifling' of creativity by medical training was reported. It is possible that the current surgical training model provides the necessary skills and abilities for the

training of safe, effective surgeons, and divergent thinking is not required. Future studies exploring whether divergent thinking influences surgeon performance, patient outcomes, well-being and other outcomes are needed. Further exploration into the effect of the surgical training process on creativity is also warranted.

This study has limitations. We chose an abbreviated version of the more comprehensive TTCT which requires 30–45 min to complete. While the ATTA has never been used in a surgical population, it has shown good predictive validity in an adult population.<sup>26</sup> Further, its short administration time (10 min) improved compliance, study feasibility and recruitment of participants. Second, grading of the tests was performed by one reviewer. However, we tested the reliability of our results against an independent second grader, calculating an excellent level of agreement. Third, given the cross-sectional nature of the survey, we cannot determine causation or control for residual confounding from variables we did not collect.

**Table 2** Multiple linear regression results—predictors of total ATTA score

Variable		Estimated $\beta$ coefficient (95% CI)	P value
Age		0.08 (−0.20, 0.37)	0.563
Surgical experience	2+ years	Ref.	
	Less than 2 years	2.53 (−0.41, 5.46)	0.090
Sex	Female	Ref.	
	Male	−3.58 (−6.25, −0.90)	0.010
Creative hobby	No creative hobby	Ref.	
	Has creative hobby	0.15 (−2.26, 2.55)	0.902
Creative friends	No creative friends	Ref.	
	Creative friends	2.41 (−0.82, 5.64)	0.142
Specialty	Other	Ref.	
	General surgery	1.16 (−1.25, 3.57)	0.338
Creative problem-solving	Not confident or neutral	Ref.	
	Confident	1.26 (−1.47, 4.00)	0.359
# of publications		0.03 (−0.06, 0.12)	0.502
Hours worked per week		0.04 (−0.04, 0.13)	0.321
Time alone per day		−0.01 (−0.51, 0.49)	0.962

ATTA, Abbreviated Torrance Test for Adults.

Longitudinal studies are required to assess the causative nature of the associated variables identified in this study. Fourth, the measurement of divergent thinking may have been influenced by motivational factors, which can affect test performance.<sup>61</sup> Lastly, despite our efforts to achieve a representative sample, participants were predominantly trainees and/or specialists in general surgeries, which limits generalisability and led to imprecise estimates of divergent thinking in underpowered subgroups.

## CONCLUSIONS

We found the divergent thinking level of surgeons and surgeon trainees was significantly higher but not meaningfully different from the average adult. Participants showed above-average ability to generate quantities and varieties of ideas but struggled to generate original ideas. The female sex was associated with higher divergent thinking ability. The results of the interviews highlighted the value of creativity for creative problem-solving in the operating room and the potential for creativity to mitigate stress and burnout. These results are likely generalisable to other surgical departments in Canada. Future research is needed to further explore the intersection between creativity in surgery, particularly with respect to the potential negative effect of surgical training on the creative potential of surgeons.

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**Contributors** AT, JWB, RS and MB conceptualised and designed the study. AT, TM and VA were involved in the testing and grading of the participant scores.

AT performed the statistical analyses, with guidance from GC, JWB, RS and MB. AT led the manuscript development, with support from GC and MB. All authors provided editorial support for the manuscript. AT is the guarantor, and accepts full responsibility for the overall content and conduct of the study, the access to the data, and the decision to publish.

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**Competing interests** AT, VA, GC and JWB report no conflicts of interest relating to this study. TM, RS and MB are affiliated with the McMaster University Department of Surgery but had no role in the assessment of any of the tests.

**Patient and public involvement** Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

**Patient consent for publication** Consent for participation in the semi-structured interviews was obtained directly from the participants.

**Ethics approval** This study involves human participants and was approved by Hamilton Integrated Research Ethics Board Project #15178. Participants gave informed consent to participate in the study before taking part.

**Provenance and peer review** Not commissioned; externally peer reviewed.

**Data availability statement** Data are available upon reasonable request. Data from this study will be made available upon reasonable request.

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## Online Supplementary Material

*eFigure 1: Violin Plots for Total ATTA score*

*eFigure 2: Violin Plots for ATTA Sub-scores*

*eTable 1: Estimated ATTA sub-scores for fluency, originality, elaboration, and flexibility*

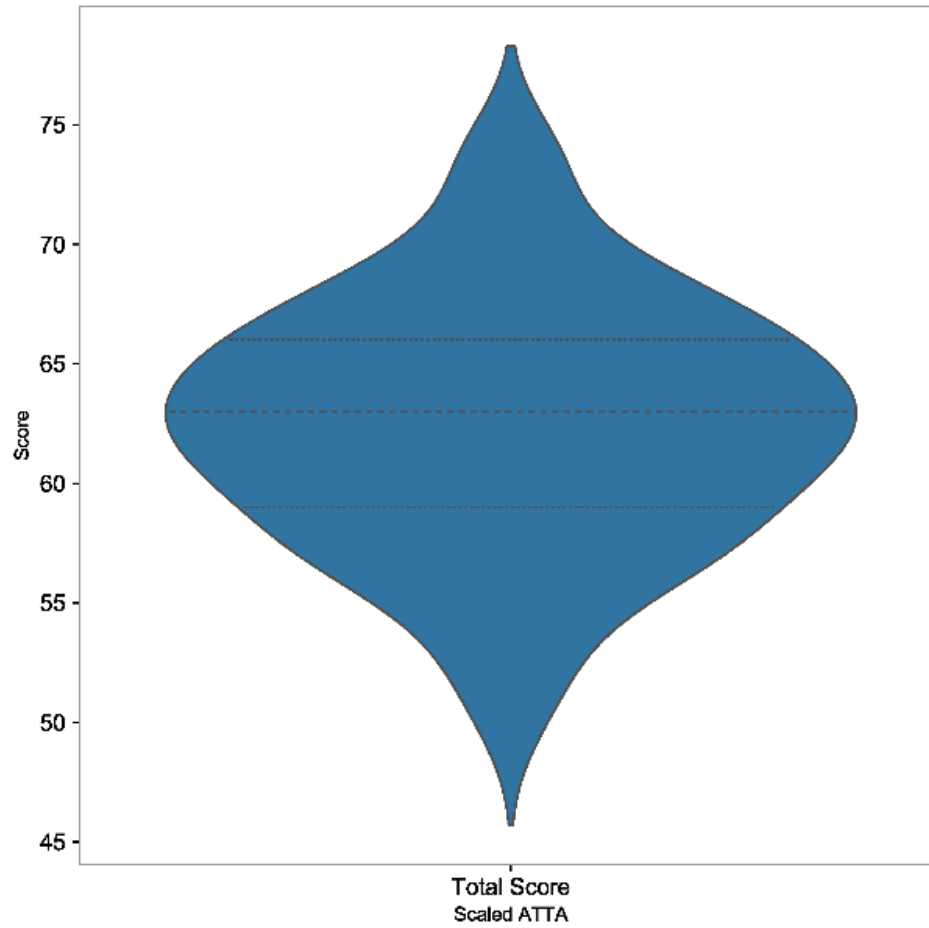
*eTable 2: Two-sided T-tests for Sub-scores vs. Average Adult Score*

*eTable 3: Mixed Model Linear Regression Results – with Specialty as a Random Effect*

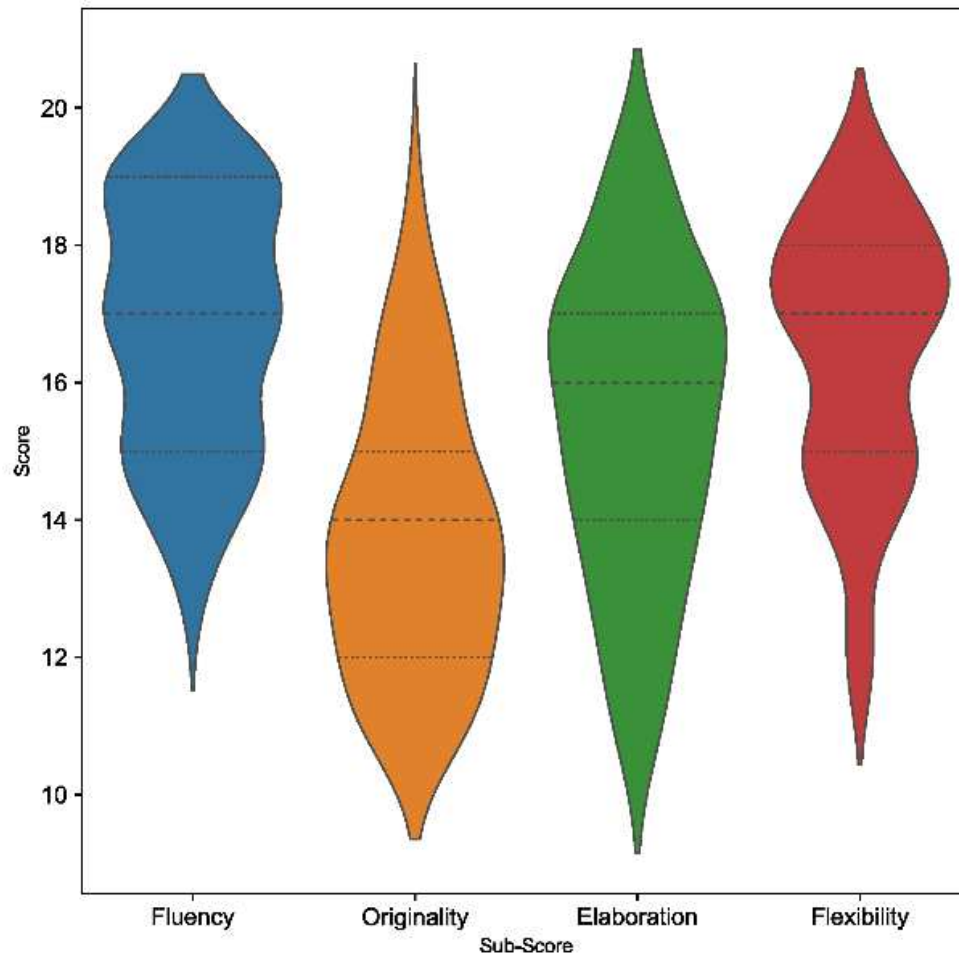
*Interview Guide*

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*eFigure 1: Violin Plots for Total ATTA score*



*eFigure 2: Violin Plots for ATTA Sub-scores*



*eTable 1: Estimated ATTA sub-scores for fluency, originality, elaboration, and flexibility abilities*

<b>Ability</b>	<b>n</b>	<b>Scaled Sub-score (95% CI)</b>
Fluency	82	16.83 (16.43, 17.22)
Originality	82	13.73 (13.29, 14.17)
Elaboration	82	15.41 (14.92, 15.91)
Flexibility	82	16.41 (16.00, 16.83)

*Average adult score is normalized to 15 for each ability. CI: confidence interval*

*eTable 2: Two-sided T-tests for Sub-scores vs. Average Adult Score*

Variable	<i>t</i>	<i>df</i>	Mean Difference (95% CI)	p-value
Total Score	4.159	81	2.39 (1.25, 3.53)	<0.001
Fluency	9.217	81	1.83 (1.43, 2.22)	<0.001
Originality	-5.777	81	-1.27 (-1.71, -0.83)	<0.001
Elaboration	1.677	81	0.42 (-0.08, 0.91)	0.097
Flexibility	6.771	81	1.42 (1.00, 1.83)	<0.001

*CI: confidence interval**eTable 3: Mixed Model Linear Regression Results – with Specialty as a Random Effect*

Variable	Estimated $\beta$ coefficient (95% CI)	p-value
Age	0.06 (-0.22, 0.35)	0.658
Surgical Experience	Ref.	
2+ Years		
Less Than 2 Years	2.09 (-0.84, 5.01)	0.158
Sex	Ref.	
Female		
Male	-3.70 (-6.33, -1.06)	0.007
Creative Hobby	Ref.	
No Creative Hobby		
Has Creative Hobby	0.24 (-2.14, 2.62)	0.843
Creative Friends	Ref.	
No Creative Friends		
Creative Friends	2.27 (-0.90, 5.43)	0.157
Creative Problem Solving	Ref.	
Not Confident or Neutral		
Confident	0.93 (-1.75, 3.62)	0.491
# of Publications	0.04 (-0.06, 0.13)	0.437
Hours Worked Per Week	0.05 (-0.04, 0.14)	0.269
Time Alone Per Day	-0.04 (-0.54, 0.45)	0.868

*CI: confidence interval**Interview Guide***Introduction & Purpose Statement:**

Thank you for agreeing to partake in this interview. The purpose of this study was to explore the level and role of creativity in surgeons. We hope by interviewing some of the ‘highly creative surgeons’ we can get a better understanding of the role of creativity in the profession and life of a surgeon. We are interested in your experience as a creative individual and surgeon, and there are no right or wrong answers.

This interview is completely voluntary, and you have the right to participate or refrain from participating. If at any point you feel like you no longer want to participate, we will end the interview and the data from your file will be deleted permanently.

The interview will be audio recorded with your permission and take approximately 30-40 minutes.

*\*Remember to avoid leading responses and explore themes that emerge outside of the interview.*

### **Background Information**

1. Let's start by having you describe your background. Mostly about demographics, professional characteristics, and creativity-related aspects of their life.
    - a. Age
    - b. Medical Role (X Year Resident, Staff Surgeon)
    - c. Creative Hobbies
    - d. Number of publications
- 

### **Definition of Creativity**

2. How would you define creativity?
    - a. Aspect about elements of creativity that they mention (ex. novelty, flexibility, usefulness)
- 

### **Creative Life**

3. Tell me a little bit about your creative life and your journey with creativity over the years.
    - a. Prompt: Start with pre-medical school.
    - b. Prompt: Medical school & residency – how did it evolve.
      - i. How did your creativity change when you became a medical professional.
- 

### **Creativity x Surgery**

4. Could you talk a little bit about the intersection between creativity and surgery?
    - a. Prompt: What does creativity look like as a surgeon?
    - b. Prompt: How do you see surgery changing in relation to creativity (ex. robotics, AI)
    - c. Prompt: Is creativity valued in surgery?
  5. What do you think about having creative hobbies as a surgeon?
    - a. Prompt: Is it important? Not important?
- 

### **Surgical Training x Creativity**

6. What would you say to surgical training programs or other surgeons with respect to creativity and creative hobbies?
  - a. Prompt: Value – does it help or hinder your work?
  - b. Prompt: Should there be creative approaches to training surgeons?