# CREATIVITY IN SURGERY

A DESIGN AND SURVEY THESIS: AN EXPLORATION OF CREATIVITY IN SURGERY

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## Lay Abstract

Creativity is an important ability in medicine. We found that creativity is being understudied in the field of medicine –only 3 studies on creativity have been conducted in surgery. Thus, we designed a survey of divergent thinking, a process used to generate creative ideas, in surgeons and surgeon trainees at the McMaster University Medical Center. We use an abbreviated version of the Torrance Test for Creative Thinking (TTCT), the most widely use measure of creativity in the world. We found that surgeons and surgeon trainees have similar divergent thinking levels to the average adult but struggled to come up with original ideas. Being male was linked to lower divergent thinking scores. Years of surgical experience trended towards a negative link with divergent thinking, suggesting that the training process may be stifling the ability to think originally.

# Abstract

**Background:** Creativity is the generation of effective and useful ideas, and it has played an integral role in the field of surgery: new techniques, technologies and practices in surgery originate from generation and implementation of creative ideas. Creativity also plays an important role in clinical problem-solving. It is therefore an important ability in the surgical profession. However, despite its importance, literature on creativity in surgery is limited.

**Research Question:** What is the current state of the literature on creativity in medicine, and how creative are surgeons, as measured by a divergent thinking tool?

**Study Design:** Scoping review & survey with semi-structured interviews.

**Primary Outcome:** Divergent thinking (as measured by the Abbreviated Torrance Test for Adults [ATTA])

**Study Setting:** McMaster University Medical Center

**Participants:** Surgeons and surgeon trainees in the Department of Surgery

**Analysis:** Descriptive statistics and regression analyses to explore factors associated with divergent thinking.

**Discussion:** We found only 54 primary studies on creativity in medicine, 3 of which were conducted in surgery. Most of the creativity research was conducted in the field of nursing. Our survey of divergent thinking found that while surgeons had an average level of divergent thinking, they struggled to produce original ideas whilst displaying high levels of fluency and flexibility. Being male was significantly negatively associated with divergent thinking. Surgical experience was marginally negatively associated with divergent thinking, suggesting that the training process may be stifling the ability to

generate original ideas. Surgeons reported a stifling of creativity in the surgical training process, which corroborated our findings.

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Research is not done in isolation – I have two fellow graduate students to thank for making this possible. Sushmitha Pallapothu and Tyler McKechnie graciously offered their time, expertise, and energy to make these studies possible. I cannot express enough thanks for their help. Jack Young from the McMaster Health Science Library also provided important support for the literature search design of the scoping review. Also, my thanks go to Vikram Arora for his help in marking the tests in such a short timeframe.

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# List of Abbreviations

Abbreviated Torrance Test for Adults (ATTA)

Amusement Park Theoretical Model of Creativity (APT)

Artificial Intelligence (AI)

Augmented reality (AR)

A Consensus-Based Checklist for Reporting of Survey Studies (CROSS)

Excerpta Medica dataBASE (EMBASE)

Hamilton Integrated Research Ethics Board (HiREB)

Intraclass Correlation Coefficient (ICC)

Idea, Development, Exploration, Assessment, and Long-Term Study Framework (IDEAL)

Medical Literature Analysis and Retrieval System Online (MEDLINE)

Medical Subject Headings (MeSH)

Minimal Theory of Creative Ability (MTCA)

Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)

Torrance Test of Creative Thinking (TTCT)

# Declaration of Academic Achievement

Alex Thabane drafted all chapters of this manuscript, which fulfills the requirements for a MSc Thesis in the Department of Health Research Methods, Evidence, and Impact at McMaster University. Alex Thabane led all aspects of this thesis under the supervision of Dr. Mohit Bhandari, Dr. Jason W. Busse, and Dr. Ranil Sonnadara, who provided feedback, guidance, and comments for each chapter.

The scoping review was led by Alex Thabane, with assistance on the literature search strategy from Jack Young at the McMaster University Faculty of Health Sciences Library. Sushmitha Pallapothu served as the duplicate screener and data extractor for the study. All aspects of manuscript development, including writing and generation of tables and figures, were performed by Alex Thabane. The scoping review has been submitted for publication to the *Creativity Research Journal*.

The IDEAS study protocol was designed solely by Alex Thabane, in collaboration with the thesis committee, and published in the journal *BMJ Open*.

The testing of surgeons was performed by Alex Thabane and Tyler McKechnie, and duplicate assessment of tests was performed by Alex Thabane and Vikram Arora. Analysis and manuscript development was performed solely by Alex Thabane. The results of the survey, reported in Chapter 4, will be submitted to a peer-reviewed journal.

*Two roads diverged in a wood, and I – I took*
*one less travelled by,*
*And that has made all the difference.*
R. Frost, The Road Not Taken (1916)

# Chapter 1

## Introduction

The aim of this thesis was to explore creativity in surgeons. This first chapter covers the meaning of creativity, including its definition(s) and the existing explanatory theories, the measurement of creativity, the relationship between creativity and innovation, and the role of both in surgery. A summary of the existing literature on the topic is expounded, the rationale and objectives of the thesis are made explicit, and key methodological issues encountered in the design and conduct of the thesis are described. The second chapter, containing the scoping review of the existing literature on creativity in medicine – the results will be submitted for publication in a peer-reviewed journal. The third chapter contains the protocol for the creativity survey of surgeons, utilizing a tool for the measurement of divergent thinking; the statistical analysis plan and dissemination strategy are described in full – it has been published in the journal *BMJ Open*. The fourth chapter contains the results of the survey of divergent thinking in surgeons, including the results of the regression analysis exploring factors associated with divergent thinking ability – the results will be submitted for publication in a peer-reviewed journal. The fifth chapter offers a summary of the thesis and implications of the thesis.

# 1.1 Creativity

### *1.1.1 What Is Creativity?*

There is, perhaps, no single answer to this question. A survey of artists (i.e., painters, sculptors, architects, designers) and psychology students found only one commonality in their definition of creativity: that the creative person has many ideas [1]. The standard definition of creativity, originating from the 1950s [2], contains two ingredients – originality and effectiveness (or usefulness) [3]. This definition, considered the 'state of the art' reference [4], is seemingly broad and ambiguous. What constitutes originality or usefulness? This ambiguity is not a limitation, but an inherent quality of creativity itself. In many ways, creativity defies precise definition [5].

Until 1950, empirical research on creativity was largely lacking. J.P. Guilford was the first to illuminate this void, providing the earliest scientific conceptualization of creativity and highlighting the importance of creativity research for society [6]. His call to action stimulated an exponential rise in research in the field of creativity during the second half of the 1900s and into the 21st century. In the last 70 years, creativity researchers have explored its essence from many angles including the effect of the environment on creativity, the role of the individual in creativity, the role of society and culture in creativity, and the integration of creativity into daily life [7]. A wide range of theories have sought to explain the nature of creativity and guide its measurement. Broadly, these theories can be categorized into 5 types: structural theories of creativity, componential theories of creativity, theories of creative drive, process theories of creativity, and longevity theories of creativity (*Table 1*) [8].

One of the earliest structural models of creativity, known as the "4 Ps" model [9], describes it as a multidimensional construct that involves the creative *person*, the creative *process*, the creative *product*, and the creative *press* (or environment). In this model, creativity manifests simultaneously at 4 levels: the creative individual, with his personality and characteristics, engages in the creative process within a given environment/context, resulting in a creative product. The 4 Ps model suggests that to comprehensively analyze one's creative ability, a holistic analysis of each of these areas is required. More recently, the Five As Framework – Actor, Action, Audience Artifact, and Affordances – aimed to build on the work of the 4 Ps model, including sociocultural and ecological psychology and theories of the mind to provide a more complete explanation of creativity [10]. Beghetto & Kaufman have added a provided developmental-structural theory of creativity with their The Four Cs Theory [11], consisting of mini-c (personal creativity), little-c (everyday creativity), pro-c (expert creativity), and Big-C (genius creativity). One of the most debated elements in creativity research and creativity – the generality or domain-specificity of creativity – was addressed with the Amusement Park Theoretical (APT) Model of Creativity, which used the amusement park as a metaphor to describe the stages of creativity, including initial requirements (i.e., intelligence, motivation, suitable environment), general thematic areas (i.e., creativity in science, interpersonal relationships, writing, art), domains (i.e., sculpture or painting in the arts), and micro-domains (i.e., psychologist sub-specialities within the profession of psychology) [12]. These structural theories, which have their similarities and differences, have aided in outlining the field of play within creativity research, providing useful angles from which one can understand, assess, and cultivate creativity.

The ingredients necessary for creativity have also been theorized to understand the relevant skills and knowledge necessary. The Componential Model of Creativity suggested that a combination of 4 main ingredients were necessary for creativity: domain-relevant skills (i.e., skills, intelligence, and talent in the particular domain), creativity-relevant processes (i.e., risk-taking, skills in generating new ideas), intrinsic motivation (i.e., motivation to perform a task because it is interesting, personally challenging, or satisfying) – these 3 lie within the individual – and the social environment (including extrinsic motivators that may act as a barrier to the creative act) [13, 14]. The Investment Theory of Creativity [15] and Triangular Theory of Creativity [16] provide further conceptualization of creativity and its necessary components. Additional theories on creative drive, such as the Evolving Systems approach [17], the Reciprocal Model of the Creative Process [18], and the Matrix Model [19], seek to answer the question about what drives humans to be creative, and the underlying mechanisms which fuel it. Across the theories of creative drive, intrinsic motivation is a recurring element which suggests its integral role in one's drive to be creative [8].

Guilford's Structure of the Intellect Model [20] was the first scientific conceptualization of the creative process. Consisting of divergent and convergent thinking, this model has been the framework for many creativity tests including the Torrance Test of Creative Thinking (TTCT) [21]. Other theories explicating the process of creativity include the Generate-Explore (Genexplore) Model [22], the Blind Variation and Selective Retention Theory [23], and the Associate Theory [24]. Finally, theories surrounding what makes creative products stand the test of time provide useful insight into creative geniuses and

what makes their work last. The Systems Model analyzes creativity from a social perspective, considering it to be made of three different sources: the cultural domain, the individual within the domain, and the 'gatekeepers' which accept or reject creativity [25, 26]. In contrast, the Propulsion Model of Creativity describes a creative product as one that interacts with its context, propelling the field forward [27].

| Theories of Creativity | | | | |
|---|---|---|---|---|
| **Structure** | **Ingredients** | **Drive** | **Process** | **Longevity** |
| Four Ps Framework [9] | Componential Model of Creativity [13, 14] | Evolving Systems Approach [17] | Structure of the Intellect [20] | Systems Model [25] |
| Five As Framework [10] | Investment Theory of Creativity [15] | Reciprocal Model of the Creative Process [18] | Geneplore Model [22] | Propulsion Model of Creativity [27] |
| Four Cs Theory [11] | Triangular Theory of Creativity [16] | Matrix Model [19] | Blind Variation and Selective Retention Theory [23] | |
| APT Model of Creativity [12] | | | Associate Theory [24] | |

***Table 1:*** *Theories of Creativity [8]*

### *1.1.2 Measuring Creativity*

Given the complexity of creativity and the heterogeneous literature explaining its essence, as exemplified by the vast range of creativity theories, the measurement of creativity is one of the fields most controversial issues [28]. Partly driven by the ambiguity in the definition of creativity, there exists over 200 creativity tests from which creativity can be

measured (examples in *Table 2*, organized using the 4Ps Framework) [29]. Measuring the creative process is the most common approach to measuring creativity, accounting for over 50% of creativity measurement studies [28]. Divergent thinking tests, such as the TTCT [21], are the most widely used, typically measuring the constructs of fluency, flexibility, elaboration and originality outlined by Guilford in his Structure of the Intellect Model. The flexibility and exploration fundamental to divergent thinking have been found to be a reliable proxy for creative ability and potential [30, 31]. In particular, the TTCT has demonstrated the ability to predict adult creative achievement [32]. That said, the validity of divergent thinking tests has been questioned, and creativity researchers acknowledge the need to perform multiple tests, exploring all aspects of creativity due to its multidimensional nature [32, 33].

| **Creativity Measurement Tools** | | |
|---|---|---|
| **Approach** | **Focus** | **Instrument** |
| *Process* | Creative processes or skills associated with creativity | • Torrance Test of Creative Thinking (TTCT)<br>• Structure of the Intellect Divergent Production Tests |
| *Person* | Personality traits or creative achievements | • Creative Personality Scale<br>• How Creative Are You? |
| *Product* | Creative products | • Consensual Assessment Technique |
| *Press* | Work environment or climate | • Siegel Scale of Support of Innovation<br>• Work Environment Inventory<br>• KEYS: Assessing the Climate for Creativity |

***Table 2:*** *Approaches to Measuring Creativity [28]*

The creative process, and the role of divergent thinking in it, can be illustrated by the Creativity Diamond Framework (*Figure 1*) [34]. As described by this framework, which is based on the existing creativity theories and over 20 PhD theses, the divergent phase of the creative process involves the generation of ideas for consideration, followed by a convergent phase which selects preferred ideas – tests such as the TTCT and the Abbreviated Torrance Test for Adults (ATTA), its abbreviated version, measure the first phase of this process. After completion, the creative process can be iterated upon itself, allowing the further development and refinement of the ideas generated. The framework also includes various types of tools and approaches for thinking creatively, including brainstorming, design thinking, deductive and inductive reasoning, and morphological analysis [34].

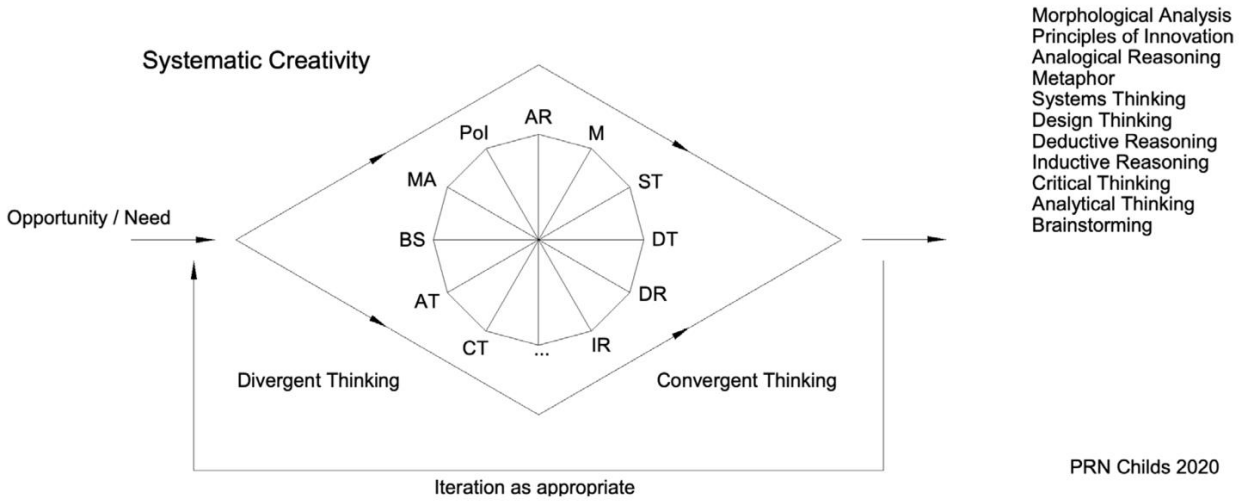


***Figure 1****: Creativity Diamond Framework [34]*

### *1.1.3 Creativity, Innovation and Surgery*

The original Greek term from which surgery is derived – *cheirourgia,* meaning "working with the hands" [35] – suggests that surgery may be more similar to traditionally creative professions like painting, sculpting, and music than one might think. The focus on creativity in surgical addresses [36], lectures [35], and editorials [37, 38] further insinuates to the important role of creativity in the success and advancement of the profession – it has even been said that the field of surgery "will continue to breathe only with creativity and innovation as its lifeblood" [38]. In particular, the function of creativity in innovation is one of its most important roles in surgery.

Innovation is an essential skill in the 21st-century [39]. It is at the heart of the modern world, and its fruits are what differentiates today's world from the pages of history. Innovation, defined as "the creation and implementation of new processes, products, services, and methods of delivery which result in significant improvements in outcomes, efficiency, effectiveness, or quality" [40], has consistently played a role in the evolution of the field of surgery. Early surgeries, performed without anesthesia and adequate medical knowledge or tools, were torturous for the patient, frequently leading to mortality [41]. It was only through the innovative thinking of daring physicians willing to test unconventional hypotheses, such as Henry Jacob Bigelow's novel work in surgical anesthesia [42] and Joseph Lister's research on antisepsis [43], that surgery began to bear the promising fruit of improved prognosis and survival. Modern surgery is indebted to the innovative ideas of the creative surgeons of the past, and the implementation of their ideas and solutions in the operating room. When revisiting the definition of innovation, two key elements are evident: creation and implementation. Thus, preceding the

implementation of any new innovative idea in surgery is the creation and ideation of the idea itself. Creativity is the seed by which innovations in surgery are born [44].

Surgeries are immeasurably safer now, with the typical individual undergoing an average of nine surgical procedures over an 85-year lifespan [45]. Consequently, the role of creativity & innovation in surgery has pivoted from reducing mortality to improving recovery and patient quality of life, reducing the risk of complications, and improving the efficiency and effectiveness of the surgical process and the overall healthcare system. Enhancements in surgical methods, such as the transition to minimally invasive surgeries, have significantly improved the surgical experience for patients, improving clinical outcomes and reducing overall costs [46-48]. Newer surgical technologies employing artificial intelligence (AI) and augmented reality (AR) are already showing promise in orthopaedics and will find growing acceptance as they become more affordable and improve outcomes vs. conventional tools [49].

Despite the long history of creativity & innovation in surgery, surgical culture has been described as traditional, change-averse, and antagonistic to innovators [50]. Demonstration of safety and efficacy in the form of randomized controlled trials is typically the standard for the integration of a new device, product, procedure, or method into the healthcare system. And rightly so. However, it often takes many years of unsuccessful cases and incremental adjustments before a surgical innovation begins to show fruit, as demonstrated by the adoption of atrial switch operations (Jatene procedure) in the 1970s and 1980s, which resulted in a 33% mortality rate in two early case studies [51]. Whilst ethical integrity and the Hippocratic oath must be central to all

actions taken inside the operating room and at the bedside, a pragmatic and creative pathway for the development and integration of surgical innovations is necessary. Frameworks such as the Idea, Development, Exploration, Assessment, and Long-Term Study (IDEAL) framework have been established to provide such a pathway for new innovations [52]. However, for these frameworks to be effective, surgeons with the necessary creative thinking ability to ideate such innovations are needed.

There are several ways in which the field of surgery could use an injection of creativity & innovation. The modern surgical residency program, based on William Halsted's apprenticeship-style residency training model at Johns Hopkins in the early 20$^{th}$ century [53, 54], has been criticized for being unsatisfactory and not providing the necessary training or case load required to reach technical competency [55-57]. Moreover, the today's surgeons report struggling with burnout, confusion in technique selection, unequal learning opportunities, neglect, and responsibility misassignment [58]. The lack of adequate knowledge is particularly disturbing: in a study of 348 general surgery residents from 6 surgical programs, 31% required remediation, most often due to a lack of medical knowledge [59]. With an estimated 17% attrition rate in residency programs [60], reaching as high as 30-39% in some programs [61, 62], a redesign of the surgical training system is required to ensure an adequately staffed and competent surgical department capable of handling the ever-changing landscape in the operating room. Novel approaches, stealing the best concepts from training programs in other disciplines such as business, sports, and aviation, could provide the innovations needed to better train surgeons. Creative ideas in technique, instrumentation, and procedure, which

improve outcomes and the surgical experience for both the patient and surgeon, are of interest.

The emergence of new technologies has frequently stimulated progress in surgery: the rise of endoscopy in surgery slowly developed over time, limited by the available technologies for light sources, instrumentation, and tools [63]. As superior technologies for electric lighting, telescopes, and devices for insufflation and thermocoagulation emerged in the 20$^{th}$ century, endoscopy was able to take flight and supplant previous techniques and procedures across a wide variety of surgical specialties [50]. New surgical devices, such as the DaVinci surgical system, are manifestations of the effects of technological advances in electronics, manufacturing, and imaging on the field. These examples illustrate the value of being able to think creatively and combine developments in multiple areas to generate effective and safe innovations in surgical methods and practice.

The surgical innovations of tomorrow are likely to result in an entirely different surgical experience for both the patient and the surgeon. However, preceding the implementation of such novel ideas, products, or solutions, is the ideation of the novel idea, product, or solution itself. The surgical innovations of tomorrow are dependent on the ability to think creatively today.

## 1.2 Background

An examination of the existing literature on creativity in surgery, particularly with respect to the measurement of creativity in the surgical population, suggested the need for a scoping review on the topic and indicated that more studies are required to better understand the role and importance of creativity in surgery. However, a growing literature on creativity in medicine at large illuminates the creativity crisis at hand.

Creativity can be cultivated and trained [64-66]. Yet, recent literature has suggested that medical school education, a highly formative period in the surgeon's professional life, may be limiting their ability to think creatively. A pilot study exploring the effect of medical education on divergent thinking in resident physicians found a significant negative correlation between residency year and problem-finding ability and divergent thinking (using ideation tasks adapted from Chang & Runco [67]) [68]. This is a worrying finding, given the importance of divergent thinking in creativity and innovation. Furthermore, a study on gifted medical students demonstrated that the academic success of medical students was significantly correlated with originality as measured in divergent thinking tests, as well as convergent thinking test sub-scores for drawing conclusions and recognizing assumptions [69]. It appears that the medical education process is stifling the very skills that enable the success of its trainees in the classroom and the ideation of the surgical innovations needed to treat patients. Creativity in surgery is being stifled [70].

The lifestyle of the surgeon – in particular, the long hours of work and sleep deprivation [71] – has also been found to limit creative ability. In anesthesia residents, sleep

deprivation was found to negatively impact levels of divergent thinking (measured with the TTCT) [72]. Even the most creative surgeons cannot exercise their creative abilities without having the mental clarity and environmental conditions needed to facilitate creative thought – creative solutions are needed at the healthcare system level to provide surgeons with environmental and lifestyle conditions conducive to creative thinking, and make available to them innovation programs such as the IDEAL framework [52] to develop their creative ideas.

## 1.3 Rationale

We have identified a gap in creativity research in surgery, which is especially worrisome given the role creativity in the surgical profession. An investigation of the nature and level of creativity in surgeons will allow us to predict whether the surgery departments of the future will be equipped with the necessary creative firepower to conceive the new tools, techniques, devices, and systems that will improve effectiveness, efficiency, and quality in surgery and the overarching healthcare system. Moreover, understanding the characteristics and traits associated with creative ability will facilitate the development and adaption of new and existing training programs to cultivate creative thought and innovation. We also hope to explore the relationship between surgical staff and the healthcare system, and the associated systemic barriers/facilitators to creativity.

There is an opportunity to make a meaningful contribution to the understanding of the role of creativity in surgery. The results of the survey will serve as a launching point for further studies, such as a study of the outliers on both sides of the distribution (those of

extremely low and high creativity). Qualitative studies will be required, as creativity is challenging to define, and therefore its importance may be unquantifiable by conventional metrics of success in surgery or medicine (i.e., number of publications, success cases performed, etc.). This thesis is the first step toward further illuminating the bond between creativity and surgery.

## 1.4 Methodological Limitations

There are three main methodological limitations, relating to sampling and recruitment, measurement, and analysis. Firstly, there is potential for sampling bias due to the voluntary nature of survey participation and the use of social networking for recruitment. It is possible that participants who were willing to participate were surgeons who thought themselves highly creative and were unafraid of the potential negative results of the study. Also, several of the surgeons who agreed to participate had personal relationships with the study team, which may have led to a social clustering effect regarding the creative ability of the participants. We have mitigated this through efforts to diversify our sample population by age, experience, and speciality. We also performed a sensitivity analysis treating surgical specialty as a random effect to address any clustering at the division level. Secondly, the measurement of creativity using the ATTA [73] is worth noting, as it is a shortened version of a larger, more comprehensive test, the TTCT [21]. This was chosen for practical reasons, and we plan to conduct a follow-up study in the same population using different measurement tools. The ATTA is a measure of divergent thinking: whilst divergent thinking tests have been widely used as a proxy for creative ability and potential [30, 31], it does not measure convergent thinking or other aspects of

creativity (i.e., person, product, press). Conclusions on the creativity of surgeons based on the results of this test may contain imprecision and limited coverage of the construct of creativity. We have mitigated this limitation by including a measure of creative self-efficacy, which has been associated with creativity measures that assess the creative person (r=0.47) and the creative product (r=0.32) [74]. Thirdly, our choice of factors for inclusion in our regression analysis was based partially on existing literature and partially on intuition and curiosity. Finding evidence linking several of the chosen factors to divergent thinking, such as years of surgical experience, was difficult due to the lack of literature on creativity in surgery. We hope to identify new factors through this study, which can be further explored in future trials.

## 1.5 Objective and Scope of the Thesis

The aim of this thesis is to design a survey study utilizing a test of divergent thinking to explore: 1) assess the breadth and depth of literature on creativity in surgery; 2) the level and nature of creativity in surgeons; 3) sociodemographic, lifestyle, and professional factors associated with higher levels of creativity; and 4) creative self-efficacy among surgeons. We are hopeful that this study will be the first of many exploring the relationship between the surgical profession and creativity.

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# Chapter 2

## State, Trends & Distribution of Creativity Research in Medicine: A Scoping Review

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# Abstract

Creativity is an important skill in medicine. We undertook a scoping review exploring research on creativity in medicine to survey the current state of the literature base. We performed a systematic literature search of PubMed, EMBASE, and PsycInfo for all published primary research studies assessing creativity in the context of medicine, with a focus on physicians or nurses. Screening, full-text review, and data extraction were performed independently and in duplicate. Fifty-four studies were eligible for review (n=11,158 healthcare personnel), of which approximately half (53%) were cross-sectional surveys. Most studies (80%) were published within the last 10 years and conducted in the field of nursing (73%). Approximately 40% of studies were conducted in Taiwan, largely driven by the efforts of one researcher. Areas of inquiry included interventions for improving creativity skills, the role of creativity in clinical practice, creativity and innovation, and the effect of creativity on burnout. 36 different tools were used to assess creativity, the most common of which was the Torrance Test of Creative Thinking (n=6); most assessment tools were either a self-reported assessment of creative ability or a test of creative process. Despite the acknowledged importance of creativity in medicine, limited formal study on this topic exists.

**Keywords**

*Medicine, creativity, scoping review*

## 2.1 Introduction

Creativity is a critical skill required in many disciplines [1], and its importance has been established in the field of higher education, business, engineering, music, management and advertising [2-5]. The same is true in medicine: medical professionals operate in a rapidly changing healthcare environment and are constantly faced with unique challenges that require new and critical ways of thinking. Creativity is essential for understanding complex cases, clinical decision-making, solving problems, communicating empathetically with patients, and spurring innovation [6-8]. Physicians acknowledge that the ability to generate new and useful solutions – to be creative – is critical to their performance and the quality of healthcare delivery [8].

JP Guilford's 1949 address to the American Psychological Association was a call to action to the scientific community to increase research efforts in creativity [9]. In the 23 years prior to his speech, only 186 out of 121,000 titles in the *Psychological Abstracts* were on the subject of creativity [9]. Creativity research was being neglected. In the decades following his address, research on the topic of creativity has blossomed – presently, there are several journals specifically dedicated to creativity research, including the *Creativity Research Journal, The Journal of Creativity, Thinking Skills and Creativity* and *The Journal of Creative Behaviour*. However, research into the intersection of creativity and medicine is sparse and scattered, despite the increase in medical research output over the last 20 years [10]. Given the role creativity will play in the present and future of healthcare, scientific research efforts exploring this intersection is essential.

For researchers to begin charting the path into the world of creativity in medicine, an understanding of the existing research on the topic is necessary. We therefore conducted a scoping review to understand the quantity, content, and composition of creativity research in medicine.

## 2.2 Methodology

We conducted this scoping review in accordance with the methodological framework described by Levac et. al [11], which built upon the Arksey-O'Malley methodological framework [12]. Five main stages make up its composition: 1) identifying the research question; 2) identifying relevant studies; 3) study selection; 4) charting the data; and 5) collating, summarizing, and reporting the results.

*Identifying the Research Questions*

The aim of this scoping review was to obtain an understanding of the existing scientific literature on the study of creativity in medicine. The objectives of the scoping review were:

1. To identify the quantity of evidence available on the study of creativity in medicine;
    a. Overall, and by specialty
2. To identify where research in the study of creativity in medicine is being conducted, by country;
3. To assess the progression in research output in the study of creativity in medicine over time, by the number of articles published per year;

4. To identify the types of evidence available on the study of creativity in medicine, by study design;
5. To assess the number of studies measuring creativity, in any form, in medical professionals
    a. To identify the types of tests being used, sorted according to the 4P (Person, Process, Product, Press) Framework [13]

*Identifying Relevant Studies*

We performed an electronic database search of the MEDLINE, EMBASE and PsychInfo databases from inception to March 14, 2023. The following keywords and Medical Subject Heading (MeSH) terms were used in the search strategy: (creativity/ OR creativity measurement/ OR divergent thinking/ OR divergent think* OR creativ*) AND (exp Medicine/ OR (medicine or medical or surgeon or doctor or physician or clinician) OR health personnel/ or exp medical sciences/). We tailored the use of subject headings to each database depending on the index structure of each respective database (**Appendix A1**). Additionally, we searched the references of relevant articles for additional relevant publications and utilized the Connected Papers platform to identify similar papers. The Connected Papers platform calculates a similarity metric based on overlapping citations and references to cluster similar papers together using a force-directed graph [14].

*Study Selection*

AT and SP performed the screening and full-text review independently and in duplicate. We resolved discrepancies through discussion until a consensus was reached.

Eligible studies were primary, original research with the objective of investigating or measuring creativity or creative ability in the context of medicine, published in a peer-reviewed journal. In this study, we limited the medical context to the medical practice or personnel of physicians or nurses. We chose to focus on this population because physicians and nurses are the spine of most healthcare systems, providing most of the health care services and constituting the vast majority (84%) of all healthcare professionals [15].

The following exclusion criteria were applied:

1) Studies in 'creative interventions' (i.e., creative art, creative writing) that do not explicitly explore the construct of creativity or creative ability as an objective or result of the intervention;
2) News articles, interviews, opinion papers, workshops, presentations, posters, dissertations, editorials, conference abstracts, books, or book chapters;
3) Studies not published in English;

Given the variation in definitions of creativity [16], we only included studies that explicitly mentioned the concept of creativity as an objective. For this review, we defined creativity as the "interaction between aptitude, process, and environment by which an individual or group produces a perceptible product that is both novel and useful as defined with in a social context" [17].

*Charting the Data*

AT and SP performed data extraction independently and in duplicate using the Covidence platform. We resolved any discrepancies during the data extraction process by discussion until consensus. Extracted data included: surname of the 1st author; title of the article; name of the journal; year of publication; country in which the study was conducted; specialty; study objective; study design; definition of creativity used or mentioned in the paper; description of the population; total number of participants; aspect of creativity being measured (i.e., creative process, creative personality, creative environment, creative product); and tool used to measure creativity.

*Collating, Summarizing, and Reporting the Results*

We summarized the results of the literature search, screening process, and full-text review using a PRISMA diagram [18]. We also performed a narrative summarization of the data as well as a graphical representation of the data relevant to the research objectives (using Microsoft Excel). The 4Ps Creativity Framework was utilized to classify the creativity tests according to the aspect of creativity being measured. Two additional categories, creative self-perception and 'other', were added to categorize tools that involved self-rated assessments of one's creativity belief or did not fit into the aforementioned categories [13].

## 2.3 Results

*Search Results*

After the removal of 360 duplicates, 3218 citations were included for screening. After screening and full-text review, we identified a total of eligible 41 papers from the database

search. We also found an additional 13 papers from the bibliography search and the Connected Papers literature search (**Figure 1**).

Thus, we included 54 studies on creativity in medicine in the present review, with a total of 11,158 medical professionals (**Supplementary Table 1**).

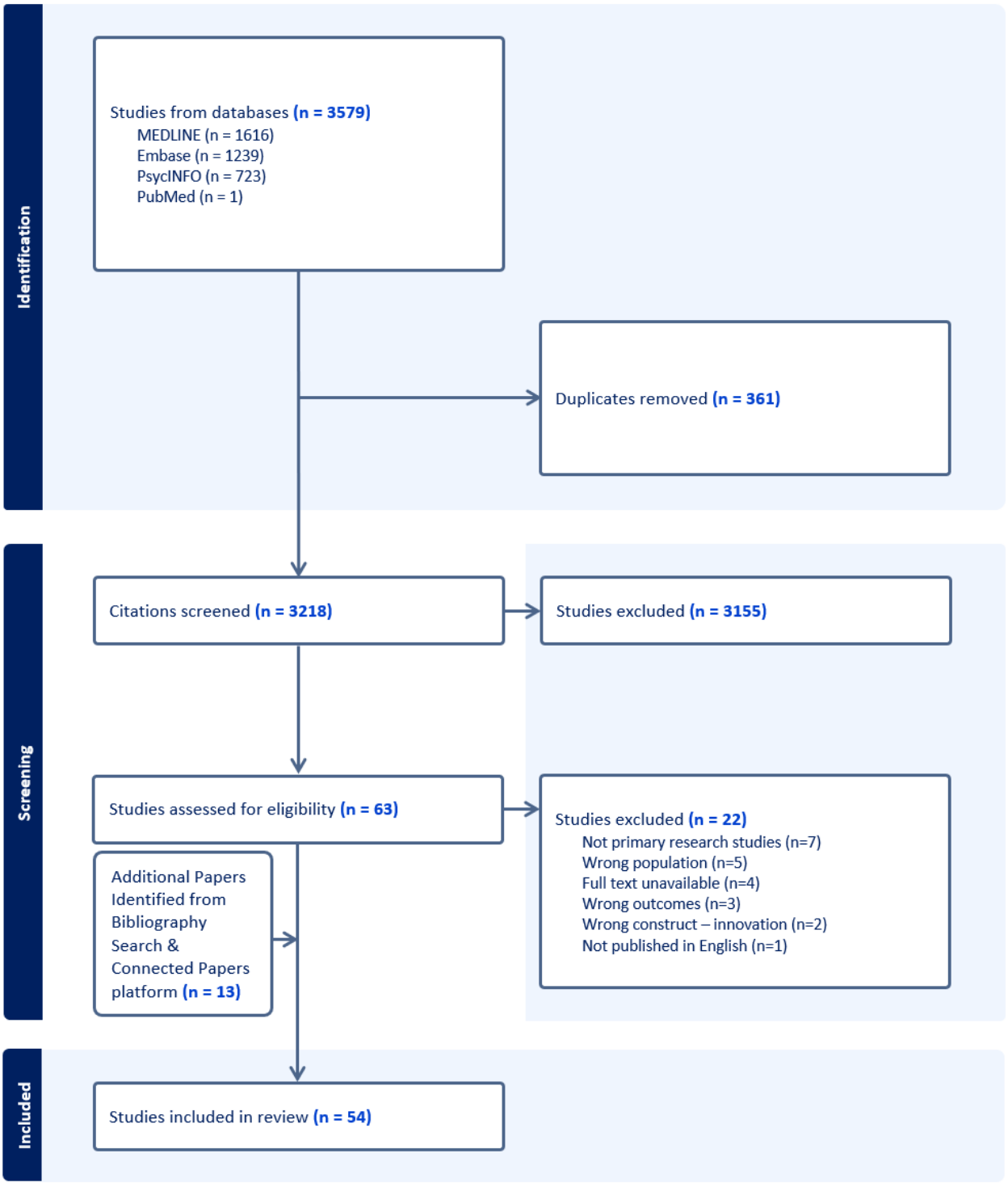


**Figure 1:** *PRISMA diagram of the study selection process.*

*Geographical Locations of Creativity Research*

Most studies exploring creativity in medicine were conducted in Taiwan (n=21), followed by the United States (n=7) and Iran (n=5). The remaining countries with publications on the topic produced no more than 3 studies: these included Spain (n=3), Sweden (n=2), China (n=2), Egypt (n=2), South Korea (n=2), Australia (n=1), Canada (n=1), Lebanon (n=1), India (n=1), Netherlands (n=1), Norway (n=1), South Africa (n=1), Thailand (n=1), Tunisia (n=1) and the United Kingdom (n=1) (**Figure 2)**.

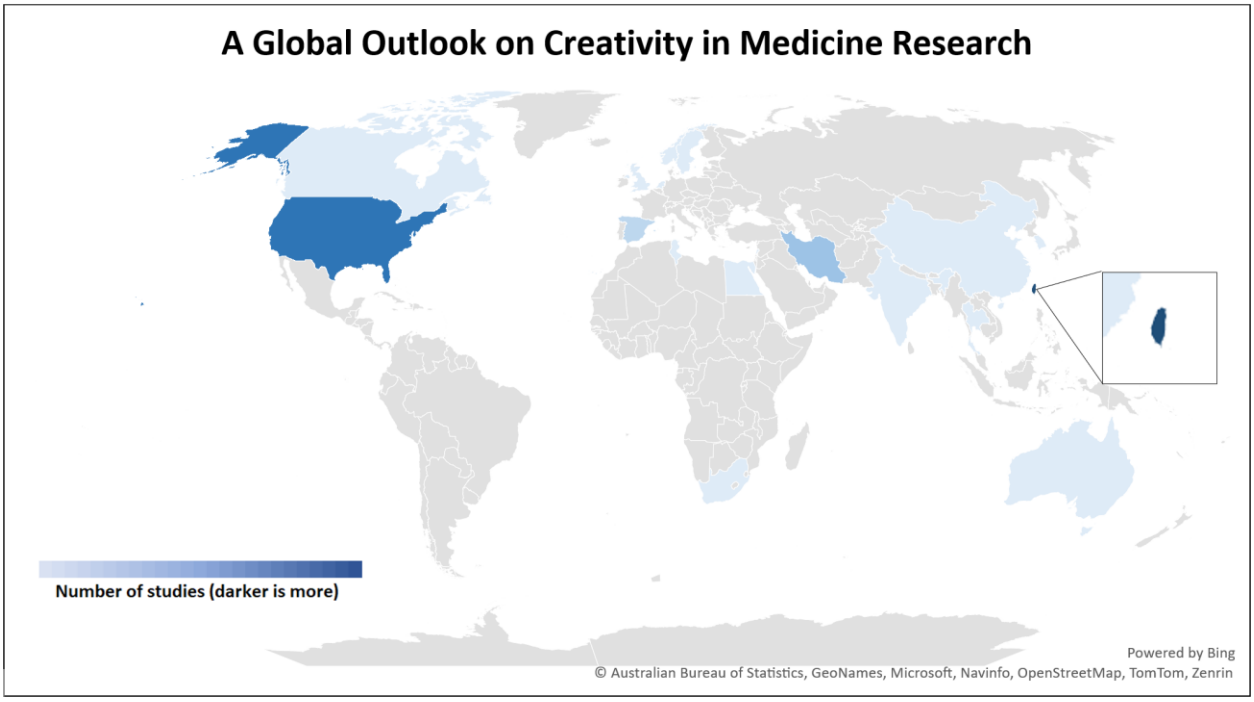


**Figure 2:** *Research Output on Creativity in Medicine by country*

*Creativity Research Over Time*

The first creativity research papers in medicine were published in the mid 1970s. However, limited research output on creativity in medicine was observed for most of the 20th century. Creativity research in medicine began to increase in the last 10 years, largely due to the research initiatives in Taiwan. In particular, the research output of 1 Taiwanese researcher over the last 6 years comprises 26% (n=14) of all articles on creativity in

medicine. Nonetheless, research on creativity in medicine has never exceeded 12 publications in one year **(Figure 3).**

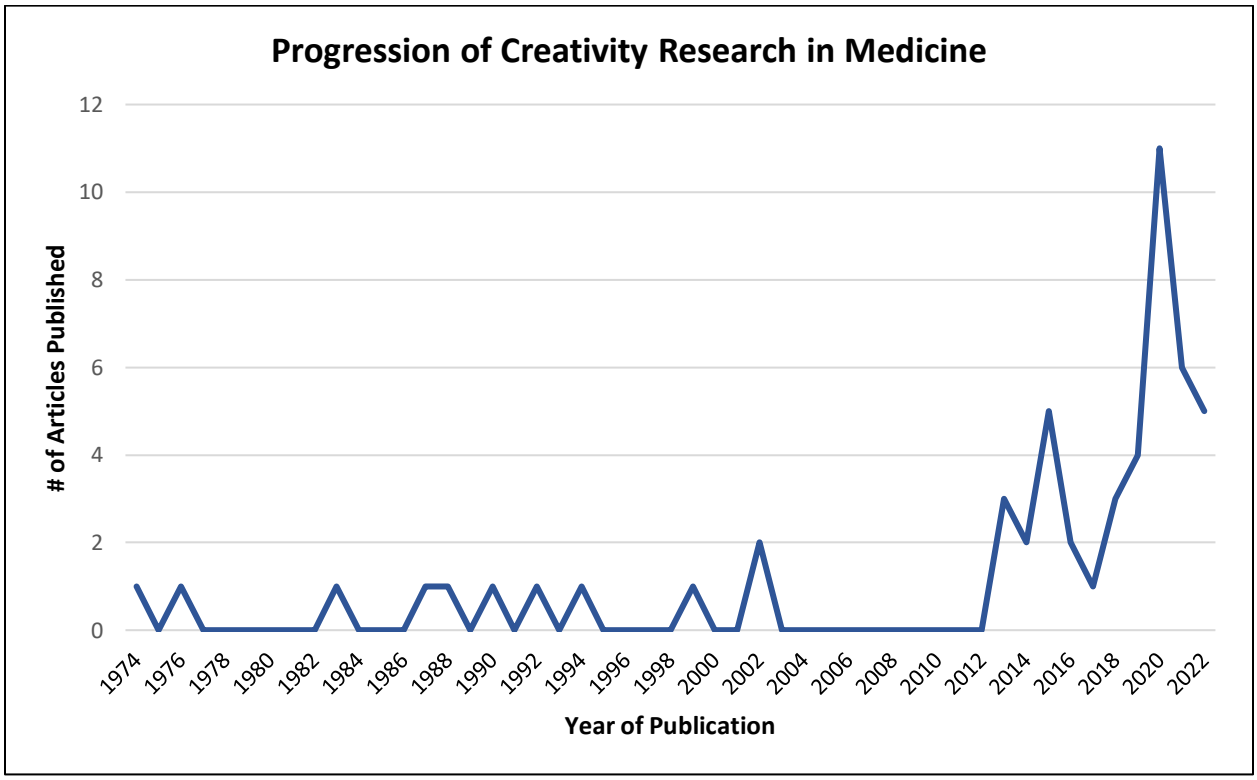


**Figure 3:** *Progression of Research Output Over Time*

*Creativity Research Output by Specialty*

The majority of research in creativity was published in the nursing specialty (n=40 papers, 73%). Creativity research in physicians is almost non-existent, with the exception of a few studies in medical education (n=7), surgery (n=3), and family medicine (n=2) (**Figure 4**).

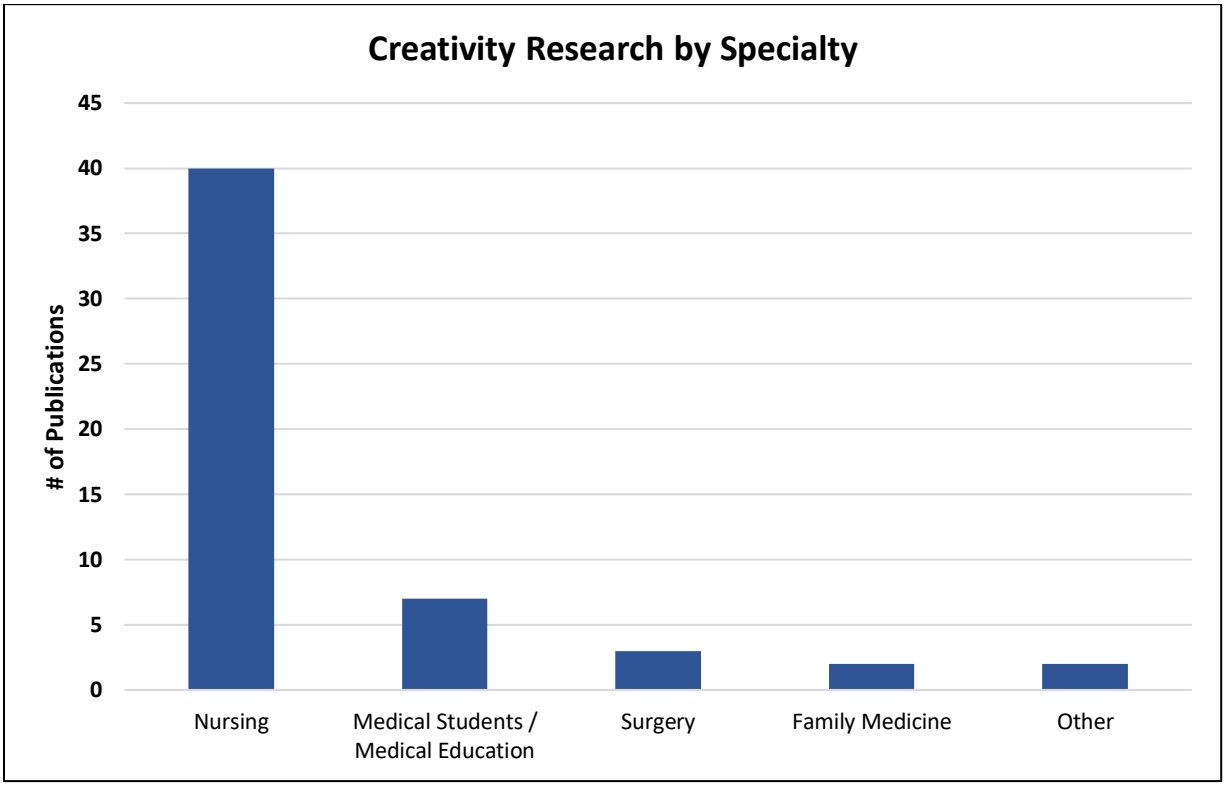


**Figure 4:** *Creativity Research Output by Medical Specialty*

*Study Designs*

More than half of eligible studies used a cross-sectional design (n=29). Additional study designs utilized included non-randomized experimental/intervention studies (n=13), qualitative studies (n=6), case report/series (n=2), citation analyses (n=2), prospective cohort studies (n=1), and randomized controlled trials (n=1) (**Figure 5**).

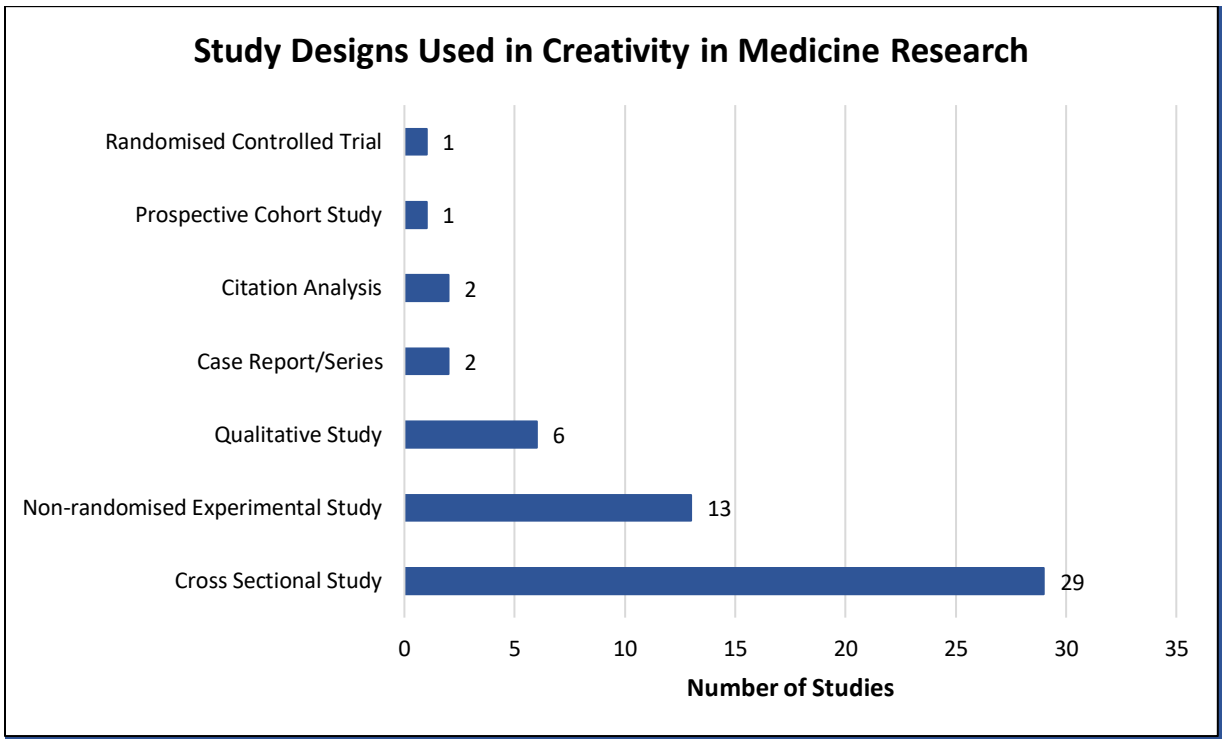


**Figure 5:** *Study Designs Used in Creativity in Medicine Research*

*Areas of Inquiry*

Creativity was assessed in a wide range of contexts. 28% of studies explored the use of interventions or programs to improve creativity skills or the ability to teach creativity (n=15). A common study by Taiwanese researchers involved the use of capstone courses to improve creative ability in nursing students. Other areas of inquiry included the role of creativity in clinical practice (n=5), creativity and innovation (n=5), the relationship between creativity and burnout (n=4), levels of creative ability (n=4), creativity and job design, well-being, and satisfaction (n=3), creativity and productivity and academic achievement (n=3), creativity and research (n=2), creativity and personality and thinking styles (n=2), the effect of creativity on diagnostic accuracy (n=1), creativity tool development (n=1), and the effect of video games on creativity (n=1) (**Table 1**).

| Areas of Inquiry | # of Studies |
|---|---|
| Teaching and Improving Creativity Skills | 15 |
| Creativity in Clinical Practice | 5 |
| Innovation | 5 |
| Burnout | 4 |
| Exploring Creative Ability | 4 |
| Job Design, Well-Being & Satisfaction | 4 |
| Teamwork & Group Creativity | 4 |
| Job Design, Well-Being & Satisfaction | 3 |
| Productivity & Academic Achievement | 3 |
| Creative Research | 2 |
| Personality & Thinking Styles | 2 |
| Diagnostic Accuracy | 1 |
| Tool Development | 1 |
| Video Games on Creativity | 1 |

**Table 1:** *Areas of Inquiry in Creativity Research in Medicine*

*Measuring Creativity – Aspects and Tools*

78% of studies (n=42) used at least one measurement tool to measure creativity. Across the 42 studies, a total of 36 different measurement tools were utilized. The most popular tool used was the Torrance Test of Creative Thinking (TTCT; n=6), which was developed by EP Torrance and is the most popular creativity measurement tool. A creativity measurement tool developed in China was used several times to assess the creativity of teams (n=5). (**Supplementary Table 2**).

The most common aspect of creativity measured was creative process, which included measures of divergent thinking such as the TTCT and the Guilford Creativity Questionnaire. – both tests were developed in the 1960s. A figure illustrating the distribution of the tests by the aspect of creativity being measured is available in **Figure 6.**

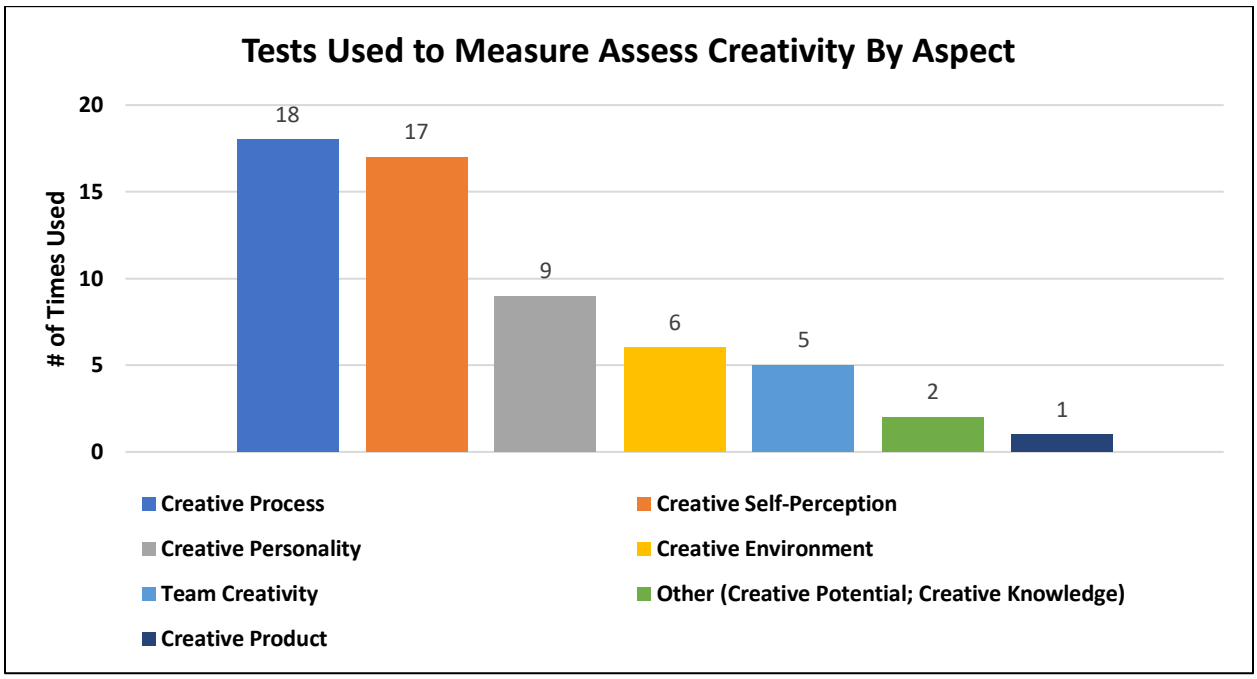


**Figure 6:** *Types of Tests Used to Assess Creativity, By Aspect*

## 2.4 Discussion

This study is the first review of creativity research in medicine. 54 studies on the topic have been published, the majority of which were published in the last 6 years and conducted in the field of nursing (largely due to the efforts of Taiwanese nurses). One Taiwanese researcher alone produced close to 30% all creativity in medicine publications. Most studies (n=29) were cross-sectional in design, and areas of inquiry included the use of interventions and programs to improve creativity skills, the role of creativity in clinical practice, creativity and innovation in medicine, and the role of creativity in burnout. 36 different tools were used to assess creativity, with no test dominating the landscape.

This scoping review illuminates the lack of literature on the topic of creativity. Whilst research efforts have improved in the last 6 years, the output of research on creativity in medicine pales in comparison to the over 1 million papers which are uploaded each year onto the PubMed database alone [19]. This indicates a lack of appreciation of the role and importance of creativity in medicine, limited governmental support for creativity research in medicine, and the need for a medicine-specific measurement tool.

The standard definition of creativity consists of two components: originality and effectiveness [20]; for an idea to be creative, it must be new, and it must be useful. But what it means to be creative as a family physician, or a nurse, or a surgeon has not been well defined in the literature. Creativity contains an element of domain specificity [21, 22]: investigating the exact role of creativity in clinical practice and articulating what it means to be creative as a medical professional could lead to an increased appreciation of why creativity is important in medicine, and stimulate future research on the topic. Physicians and nurses agree that creativity is an important skill required in medical professions [23, 24], but more research is needed to articulate and understand its role.

Taiwanese researchers conducted close to 40% of the existing research in creativity in medicine, illustrating the importance of government support of research efforts on creativity. The Creative Education White Paper, released in 2003, mandated the Taiwanese government to focus on improving creativity in its students, which led to an influx of courses, interventions, and subsequent research into creativity [25]. If research on creativity in medicine is to grow and develop around the world, support from all levels will be necessary. Government, educational institutions, hospitals, and medical

professionals themselves all have a role to play in encouraging research on creativity in medicine. Creating research grant opportunities could be a way to stimulate research on the topic, as the receipt of funding and grants can have a strong effect on improving publication output [26].

Of the 36 different creativity tools utilized, only 1 tool – the Chinese Nursing Practicum Creative Process Questionnaire – was specifically designed for use in medical populations. Developing more healthcare-specific creativity measurement tools validated in medical professionals could facilitate creativity research efforts in medicine and help account for the domain-specific nature of creativity. Also, a wide distribution also exists respect to the aspects of creativity being measured across studies; a healthcare-specific tool, or a combination of different tools, that measures not only the creative process but also the personality, product, and environmental aspects of creativity would allow for comprehensive, holistic assessments of the creativity of medical professionals.

This study has several strengths. Firstly, we conducted a comprehensive search of 3 large databases that cover a wide range of disciplines. We also utilized the Connected Papers platform, in addition to perusing the references of relevant articles, to identify related papers that may not have been captured in our database searches. Secondly, we conducted all screening, full-text review, and data extraction independently and in duplicate, which has been found to reduce the number of missed studies and number of errors during data extraction [27, 28]. Thirdly, we assessed the types of study designs, the types of measurement tools that were used, aspects of creativity most frequently assessed, and areas of inquiry: this provides unique insights into the existing landscape of research and

can help guide future research plans. Our study has a couple of limitations: mainly, the exclusion of studies that were not published in English and the exclusion of unpublished abstracts which may increase the vulnerability of this review to publication bias. However, we only excluded 1 study during full-text review due to not being published in English; coupled with the extensive database search, we believe that the scientific literature on the topic was adequately captured.

## 2.5 Conclusion

Despite the acknowledged importance of creativity in the medical profession by healthcare professionals, creativity research in medicine is limited. Only 54 studies have been published all time, mostly in the field of nursing. Taiwanese researchers have produced close to 40% of the existing research, driven largely by the efforts of one researcher and likely stimulated by government initiatives around fostering creativity in students. Similar institution-based initiatives would greatly facilitate a worldwide uptake in medical creativity research and help further develop a field that remains in its infancy but is ripe with potential. With only 1 of the 36 tools used to assess creativity being specific to medicine, a healthcare-specific creativity assessment tool could facilitate increased understanding and research into the nature of creativity in medicine.

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**Declaration of Interest Statement**

All authors report no conflicts of interest relating to the work in this project.

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# 2.7 Appendices

## *2.7.1 Appendix A1: Included Studies*

| **Title** | **1st Author Last Name** | **Journal Name** | **Year** |
|---|---|---|---|
| Creativity in Work: An Educational Program for Improving Nurses` Productivity | Abd-Elrhaman | International Journal of Innovative Research and Development | 2018 |
| Thinking styles and creativity preferences in nursing. | Almansa | Creative Nursing | 2013 |
| Investigating the Creativity and Its Influencing Factors among Medical Students | Amiri | International Journal of Health Studies | 2019 |
| Creativity and its determinants among medical students. | Amiri | Journal of Education and Health Promotion | 2020 |
| The Relationship Between Burnout and Health Professionals' Creativity, Method, and Organization. | Barroso Alonso | Creative Nursing | 2020 |
| Nurses' creativity, tedium and burnout during 1 year of clinical supervision and implementation of individually planned nursing care: comparisons between a ward for severely demented patients and a similar control ward. | Berg | Journal of Advanced Nursing | 1994 |
| Effects of systematic clinical supervision on psychiatric nurses' sense of coherence, creativity, work-related strain, job satisfaction and view of the effects from clinical supervision: a pre-post test design. | Berg | Journal of Psychiatric and Mental Health Nursing | 1999 |
| Comparison of Modified Hybrid Brainstorming With a Conventional Brainstorming Program to Enhance Nurses' Innovative Idea Generation. | Boonyoung | The Journal of Continuing Education in Nursing | 2021 |
| Creativity in neurosurgical publications. | Davis | Neurosurgery | 1987 |
| Creative thought in neurosurgical research: the value of citation analysis. | Davis | Neurosurgery | 1990 |

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| The Influences Burnout and Lack of Empowerment Have on Creativity in Nursing Faculty. | Drafahl | Nursing Education Perspectives | 2020 |
| Certified nursing assistants as agents of creative caregiving in long-term care. | Eaton | International Journal of Older People Nursing | 2020 |
| Job crafting mediates the relation between creativity, personality, job autonomy and well-being in Lebanese nurses. | Ghazzawi | Journal of Nursing Management | 2021 |
| What happens to creative medical students?. | Gough | Journal of Medical Education | 1976 |
| Nurses' creativity: Advantage or disadvantage | Isfahani | Iranian Red Crescent Medical Journal | 2015 |
| Leadership, Knowledge Sharing, and Creativity: The Key Factors in Nurses' Innovative Behaviors. | Kim | The Journal of Nursing Administration | 2015 |
| The effectiveness of teaching strategies for creativity in a nursing concepts teaching protocol on the creative thinking of two-year RN-BSN students. | Ku | Journal of Nursing Research | 2002 |
| Develop a framework of creative thinking teaching mode for RN-BSN students on the basis of the creative process of clinical nurses in Taiwan | Ku | Innovations in Education and Teaching International | 2014 |
| Constructing and evaluating a nursing capstone course for cultivating creativity in RN-BSN students in Taiwan | Ku | Journal of Nursing Education and Practice | 2014 |
| Validating the questionnaire of factors influencing creative process for RN-BSN students in Taiwan | Ku | Journal of Nursing Education and Practice | 2015 |
| Evaluating creative thinking of RN-BSN students in the course of clinical case study and practicum | Ku | Innovations in Education and Teaching International | 2015 |
| Effectiveness of a Nursing Capstone Project Course in Enhancing Nursing Student Creativity | Lee | Innovative Journal of Medical and Health Sciences | 2016 |
| Relationships among psychological capital, creative tendency, and job burnout among Chinese nurses. | Li | Journal of Advanced Nursing | 2019 |
| Evaluating faculties and students satisfaction of a nursing practicum project workshop in Northern Taiwan | Liu | Journal of Nursing Research and Practice | 2018 |
| Nurturing and Enhancing Creativity of Nursing Students in Taiwan: A Quasi-Experimental Study | Liu | The Journal of Creative Behaviour | 2019 |
| Perceived Self-Efficacy of Teaching for Creativity Among Nurse Faculty in Taiwan: A Preliminary Study. | Liu | Nursing Education Perspective | 2019 |

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|---|---|---|---|
| Effect of creativity training on teaching for creativity for nursing faculty in Taiwan: A quasi-experimental study. | Liu | Nurse Education Today | 2020 |
| Inter-professional nursing education and the roles of swift trust, interaction behaviors, and creativity: A cross-sectional questionnaire survey | Liu | Nurse Education Today | 2020 |
| Predictors of self-perceived levels of creative teaching behaviors among nursing school faculty in Taiwan: A preliminary study. | Liu | Journal of Professional Nursing | 2020 |
| The association between creativity, creative components of personality, and innovation among Taiwanese nursing students | Liu | Thinking Skills & Creativity | 2020 |
| Factors affecting nursing students' creativity in Taiwan: Exploring the moderating role of creative personality | Liu | Nurse Education Today | 2020 |
| Predictors of individually perceived levels of team creativity for teams of nursing students in Taiwan: A cross-sectional study. | Liu | Journal of Professional Nursing | 2021 |
| Effect of interdisciplinary teaching on collaborative interactions among nursing student teams in Taiwan: A quasi-experimental study. | Liu | Nurse Education Today | 2021 |
| Moderating effects of task interdependence on interaction behaviours and creativity for nursing students on interdisciplinary teams. | Liu | Journal of Advanced Nursing | 2022 |
| Promoting creativity of nursing students in different teaching and learning settings: A quasi-experimental study. | Liu | Nurse Education Today | 2022 |
| The Moderating Role of Team Conflict on Teams of Nursing Students. | Liu | International Journal of Environmental Research and Public Health | 2022 |
| Effectiveness of Interdisciplinary Teaching on Creativity: A Quasi-Experimental Study. | Liu | International Journal of Environmental Research and Public Health | 2022 |
| The perceived importance and the presence of creative potential in the health professional's work environment. | Lukersmith | Ergonomics | 2013 |
| Divergent productive thinking factors and accuracy of nursing diagnoses. | Lunney | Research in Nursing & Health | 1992 |
| Authentic leadership and its impact on creativity of nursing staff: A cross sectional questionnaire survey of Indian nurses and their supervisors. | Malik | International Journal of Nursing Studies | 2016 |
| Personality and job creativity in relation to engagement in nursing. | Molero-Jurado | Annals of Psychology | 2020 |
| Satisfaction and creative inclination in a group of British general practitioners. | Morrison | Medical Care | 1974 |

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|---|---|---|---|
| Quasi-experimental study on the effectiveness of a flipped classroom for teaching adult health nursing. | Park | Japan Journal of Nursing Science | 2018 |
| Self-perceived creativity of practicing registered nurses. | Pesut | The Journal of Continuing Education in Nursing | 1988 |
| Academic achievement and creative thinking capacity in South African medical students--an empirical study. | Rothenberg | South African Medical Journal | 2002 |
| What Really Motivates Iranian Nurses to Be Creative in Clinical Settings?: A Qualitative Study. | Isfahani | Global Journal of Health Science | 2015 |
| Ethnopsychiatry fosters creativity and the adoption of critical and reflexive thinking in higher education students: insights from a qualitative analysis of a preliminary pilot experience at the Faculty of Medicine and Surgery, University of Genoa, Italy. | Siri | Advances in Medical Education and Practice | 2017 |
| The impact of individual creativity, psychological capital, and leadership autonomy support on hospital employees' innovative behaviour. | Slatten | BMC Health Services Research | 2020 |
| Relationship between Servant Leadership and its' Role on Staff Nurses' Creativity and Sustainable Development Behavior | Sorour | Assiut Scientific Nursing Journal | 2021 |
| Creativity in management in family medicine. | Stephenson | The Journal of Family Practice | 1983 |
| Creativity: A viable and valuable competency in medicine? A qualitative exploratory study. | Ten Haven | Medical Teacher | 2022 |
| The relationship of individual characteristics, perceived worksite support and perceived creativity to clinical nurses' innovative outcome. | Tsai | Journal of Clinical Nursing | 2013 |
| Relationship among clinical practice environment, creative self-efficacy, achievement motivation, and innovative behavior in nursing students: A cross-sectional study. | Xiang | Nurse Education Today | 2023 |
| Serious Game Design with medical students as a Learning Activity for Developing the 4Cs Skills: Communication, Collaboration, Creativity and Critical Thinking: A qualitative research | Zairi | La Tunisie Medicale | 2021 |

## *2.7.2 Appendix A2: Creativity Measurement Tools*

| **Measurement Tool** | **Type of Creativity Measured** | **# of Times Used** |
|---|---|---|

| | | |
|---|---|---|
| Torrance Test of Creative Thinking (TTCT) | Creative Process | 6 |
| 10-item team creativity scale developed by Yang, based on Farh | Team Creativity | 5 |
| Affective Components of Creativity Scale (ACCS) | Creative Personality | 3 |
| Visual Analog Scale (VAS) | Creative Self-Perception | 3 |
| Creative Climate Questionnaire (CCQ) | Creative Environment | 2 |
| Gough Creative Personality Scale (CPS) | Creative Personality | 2 |
| Creative Thinking Test (CREA) | Creative Process | 2 |
| Guilford Creativity Questionnaire (GCQ) | Creative Process | 2 |
| Chinese Nursing Practicum Creative Process Questionnaire (CNPCPQ) | Creative Process | 2 |
| Creativity Teaching Efficiency of Technology Institute Teacher's Scale (CTETITS) | Creative Self-Perception | 2 |
| Self-Efficacy for Creativity Teaching Scale (SECTS) | Creative Self-Perception | 2 |
| Creativity Teaching Behavior Scale (CTBS) | Creative Self-Perception | 2 |
| Attitude Toward Creativity Questionnaire | Creative Environment | 1 |
| School Creative Climate Scale (SCCS) | Creative Environment | 1 |
| Creative Environment Perceptions Scale (CEPS) | Creative Environment | 1 |
| Level of Creativity Questionnaire | Creative Personality | 1 |
| Barron Welsh Art Scale | Creative Personality | 1 |
| Unstandardized scale of creative inclination | Creative Personality | 1 |
| What Kind of Person Are You? | Creative Personality | 1 |
| Other: No Tool -- Measured by 'Innovation Experts' | Creative Process | 1 |
| Creativity Assessment Packet (CAP) | Creative Process | 1 |
| Utility Test | Creative Process | 1 |
| Possible Jobs Test | Creative Process | 1 |
| Critical Thinking Disposition Scale | Creative Process | 1 |
| Word association test by Kent and Rosanoff | Creative Process | 1 |
| 3-item scale by Oldham and Cummings | Creative Product | 1 |
| Likert Scale | Creative Self-Perception | 1 |
| 8-item Questionnaire by Carmeli and Schaubroeck | Creative Self-Perception | 1 |
| Creative Self-Efficacy Scale | Creative Self-Perception | 1 |
| 8-item scale by Lin | Creative Self-Perception | 1 |
| 2 items adapted from Zhou and George | Creative Self-Perception | 1 |
| Employee Creativity Scale | Creative Self-Perception | 1 |
| 5-Point Likert Scale | Creative Self-Perception | 1 |
| Adapted from the Creativity Development Quick Scan Instrument (CDQS) | Creative Self-Perception; Creative Environment | 1 |
| Composite of 6 Scales: Barron Welsh Art Scale, CPI Self-Acceptance Scale, CPI Good Impression Scale, CPI Achievement via Conformance Scale, SVIB Office Worker Scale, SVIB Banker scale | Other: Creative Potential | 1 |

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|---|---|---|
| Creativity Knowledge Questionnaire | Other: Creativity Knowledge | 1 |

# Chapter 3

## Investigating Divergent Thinking and Creative Ability in Surgeons (IDEAS) – A Survey Protocol

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# Abstract

A strong pipeline of creative ideas and individuals is critical if we are to tackle the complex healthcare challenges we will face in the 21st-century. The field of creativity is severely under-investigated in the context of surgery, and it is of interest to explore the level and nature of creativity in surgeons, across various specialties and backgrounds. Identifying the areas of surgery with strong and weak levels of creativity, as well as the predictors of high creativity among surgeons, may aid in the selection and training of future surgeons.

## *Methods & Analysis*

A convenience sample of surgeons from the Department of Surgery and McMaster University will be used for the recruitment of participants. The Abbreviated Torrance Test for Adults (ATTA), a 3-part test of divergent thinking ability, will be administered to measure the level and nature of creativity among surgeons. Descriptive analyses and multiple linear regression models are planned to synthesize the results of the survey and identify predictors of divergent thinking ability among surgeons.

## *Ethics & Dissemination*

Ethics approval from the Hamilton Integrated Research Ethics Board (HiREB) was obtained. No harm is expected due to participation in this study. The results of this survey will be published in a peer-reviewed journal and disseminated through conferences and presentations at the regional, national, and international levels.

### *Strengths & Limitations*

- *Strength*: Will include surgeons from a variety of ages, backgrounds, and specialties.
- *Strength*: Use of a validated, objective test of divergent thinking (i.e., ATTA)
- *Limitation:* Convenience sampling, which may cause results to not be an accurate representation of the surgical disciplines, McMaster University Dept. of Surgery, or surgical training programs at other institutions
- *Limitation:* The test is an abbreviated version of a more comprehensive tool, the Torrance Test of Creative Thinking
- *Strength:* Will explore sociodemographic, lifestyle, and professional predictors of divergent thinking among surgeons

# 3.1 Introduction

### *3.1.1 Background*

Defined as the creation and implementation of new processes, products, services, or methods resulting in significant improvements in outcomes, efficiency, effectiveness, or quality [1], innovation will be essential to address the unique and complex healthcare challenges we will face in the 21st century [2]. Antimicrobial resistance, emerging infectious diseases, and the treatment of neurodegenerative diseases are just a few of the unique challenges in modern healthcare requiring innovative solutions [3]. In particular, innovation has played an important role in the evolution of the field of surgery: advancements in magnetic resonance imaging and minimally invasive technologies have revolutionized the way we treat patients in the operating room. However, new techniques,

interventions, tools, and approaches are required to adapt to the ever-changing landscape in the operating room.

The field of surgery has been deliberately constrained by guidelines and structure: while this ensures a consistent level of care across the healthcare system, this may have led to an undervaluing of the importance of creativity in surgery. The surgery departments of the future will require open-minded surgeons with strong creative thinking ability, capable and daring enough to think outside of the box, even pushing against the guide rails of conventional wisdom when required. What surgery needs is an evidence-based blend of creativity, clinical experience, and sound research.

The ideation of novel solutions precedes any implementation of innovative products or interventions. Thus, creativity, the process which generates novel and useful outcomes (such as ideas, products, methods, or expressions) [4,5], is the currency by which we will acquire the innovative solutions required in surgery. The measurement of creative ability is therefore a useful tool for the selection and training of surgeons. Due to the complexity and multidimensional nature of the construct of creativity [6], divergent thinking is typically used as a measure of creative ability and predictor of future creative achievement [7], as it contains known factors associated with creative ability, namely fluency, flexibility, and originality [8]. The use of divergent thinking tests, such as the Torrance Test of Creative Thinking (TCTT) [9] and the Alternate Uses Task (AUT) [10], are therefore common in experimental research. These tests are useful tools in the study of creativity and will facilitate the exploration and assessment of the creative ability and creative potential of prospective and current surgeons.

The field of creativity in surgery is severely under-investigated. Previous studies around individual and team creative ability have been published [11-13], however, there is a complete dearth of evidence on creativity in surgeons. An awareness and understanding of the level and nature of the creativity of surgeons, across specialties and at all levels of the expertise hierarchy, is the first step towards tackling this issue and building a highly competent and creative pipeline of surgeons. Using a validated and tested tool for the measurement of divergent thinking [14], we plan to fill this gap and explore the level and nature of creativity in surgeons in the McMaster University Department of Surgery.

### *3.1.2 Aim*

The objectives of this survey are to explore: 1) divergent thinking ability in surgeons; 2) sociodemographic, lifestyle, and professional factors associated with higher levels of divergent thinking ability; and 3) creative self-efficacy among surgeons.

## 3.2 Methods and Analysis

### *3.2.1 Sampling Technique & Recruitment*

We will perform convenience sampling to identify and recruit potential participants: we will contact program directors and coordinators at the 11 divisions (i.e., Vascular; Urology; Thoracic; Plastic; Pediatric; Otolaryngology; Orthopaedic; Ophthalmology; Neurosurgery; Cardiac; General) of the Department of Surgery at McMaster University to identify surgical trainees and attendings within their divisions. Prospective surgeons will be provided with a synopsis of the study objectives, the benefits/harms associated with

the study, requirements for participation, and a consent form. Priority will be placed on ensuring diversity in age, gender, level of training, ethnicity/background, and surgical specialty.

Surgeons who agree to participate will be scheduled to complete our survey, which will be administered on a rolling basis and can be administered to an individual or group settings [15]. The planned start date for our study is 30 January 2023, and the anticipated date of completion is 31 August 2023.

### *3.2.2 Measurement*

On the day of testing, we will meet the participants at the scheduled time and location. After the consent form is signed, a participant characteristics form will be completed by the surgeon, without any personal unique identifiers. Information collected will include age, institutional affiliation, sexual identity, surgical discipline/specialty, years of surgical training, relationship/family status, creative self-efficacy (the belief that one has the ability to produce creative outcomes [16]), background/ethnicity, undergraduate degree (type and major), average number of hours spent alone per week, average number of hours of worked per week, the presence of creative acquaintances, friends or co-workers, average time spent reflecting/thinking per week, artistic pursuits/hobbies outside of work, research output (# of published peer-reviewed papers), leadership roles (i.e., holding of a leadership position, for example as a division head or clinical director), and the perception of whether one's work bolsters creative potential. Several of these

characteristics (listed in data analyses section) will be utilized in the regression model as predictors of divergent thinking ability.

The tool that we will utilize to measure divergent thinking ability is the Abbreviated Torrance Test for Adults (ATTA) test, a shortened form of the Torrance Test for Creative Thinking (TCTT) [9]. The ATTA was validated in a population of undergraduate and graduate level students from the Netherlands [14] and measures four norm-referenced creative abilities (Fluency – the ability to produce quantities of ideas relevant to the task instruction; Originality – the ability to produce uncommon ideas or ideas that are new or unique; Elaboration – the ability to embellish ideas with details; Flexibility – the ability to process information or objects in different ways, given the same stimulus) as well as 15 indicators of creativity. The test consists of 3 activities: 1 verbal task involving the generation of responses to a question, and 2 figural tasks involving drawing to complete incomplete figures. Each task is time-limited by 3 minutes and is proctored by an administrator familiar with the testing protocol. Additionally, creative self-efficacy will be measured using a 7-point Likert scale; creative self-efficacy has been correlated with measures of creativity [17].

Upon completion of the test, we will assess participant responses independently according to the ATTA guidelines [15]. Given the high level of reliability for the ATTA test (Kuder-Richardson 21=0.84-0.9[15]), a single reviewer trained in ATTA scoring will perform all survey assessments.

### *3.2.3 Sample Size Calculation*

To estimate the sample size required to estimate the mean of the scaled creativity score in surgeons on the Abbreviated Torrance Test for Adults (ATTA), we used the following formula:

$$n = \left(\frac{1.96 \text{ x SD}}{\text{Margin of Error}}\right)^2$$

The ATTA's standard deviation (SD) of the scaled scores was 7.87 [15] and has a range of plausible scores between 44 and 76. We created a sample size table using Microsoft Excel to explore possible sample sizes: with a standard deviation of 7.87 and a margin of error of 2, we calculated we would require 59.48, or 60 participants to estimate the mean scaled creativity score in surgeons. We intend to recruit up to 100 surgeons for the study, which will be sufficient to prevent over-fitting of the regression model.

### *3.2.4 Data Analysis Plan*

We have planned descriptive statistical calculations (mean, median, standard deviation, range) and a multiple linear regression analysis after the completion of data collection and test scoring. We will perform tabulation of participant characteristics overall and by specialty, and descriptive results of ATTA scores by specialty will be graphically displayed. We will report the estimate for creativity as a mean ATTA score with a 95% confidence interval [CI] (median with interquartile range if not normally distributed). We will use multiple regression to determine associations between the ATTA scores and key characteristics including age, sex, years of surgical training, creative self-efficacy,

undergraduate degree, hours spent alone/week, hours worked/week, and research output; the results will be reported as estimate of the association, with the corresponding 95% CI and associated p-value. We will perform an assessment of model assumptions and goodness-of-fit by examining the residuals, as well as a sensitivity analysis treating surgical specialty as a random effect to account for potential clustering or similarity of scores among participants with the surgical specialty. For each independent variable in the regression, at least 10 observations will be required for inclusion into the model; if this threshold is not met, the levels of each independent variable will be collapsed if possible, or excluded. All statistical analyses will be conducted using SPSS 26.0 [18]. The statistical analysis plan is summarized in *Supplementary File – Table 1*.

### *3.2.5 Patient and Public Involvement Statement.*

None. All participants will receive their respective survey results upon completion of grading.

## 3.3 Ethics and Dissemination

### *3.3.1 Ethical and Safety Considerations*

Ethics approval was obtained from the Hamilton Integrated Research Ethics Board (HiREB; Project #15178). Participation in the study is not likely to result in any harm or discomfort from/associated with the administration or results of the test. However, participants may feel anxious, distressed, or nervous over the timed nature of the test.

Participant confidentiality will be upheld throughout the study process. All data will be presented in aggregate at the overall level or level of division (if ≥5 surgeons are in the division). During data collection, analysis and publication, personal identifiers will not be displayed or utilized in any way. Data will be stored on a password-protected hard drive on a computer that only the research team will have access to. Participation is voluntary, and participants retain the right to withdraw their participation and data at any time.

### *3.3.2 Dissemination Plan*

The results of this study will be submitted for publication in a peer-reviewed journal. The primary investigator (AT) will present the results of this study at regional, national, and international conferences to communicate the results as well as promote the importance of creativity in medicine. We will make efforts to initiate dialogue with relevant stakeholders (surgeons; universities; hospital administrations; governments) to discuss findings, brainstorm future research questions, and translate the results of the survey into actionable items. Comparisons to other published studies of divergent thinking will provide insight into how the level of divergent thinking compares to other professions and populations.

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## Data Statement

As soon as legally and ethically possible, de-identified participant data will be available upon reasonable request.

## Author Statement

AT and MB conceived the research question. AT performed the literature review informing the background of this protocol. The study design and statistical analysis plan were designed by AT, with consultation and feedback from MB, JWB and RS. AT led the writing of this protocol manuscript, with support and editing from MB and JWB. The final version of the protocol has been reviewed and approved by all authors. All authors agree to be held accountable for the aspects of the work.

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## Conflicts of Interests

Dr. Mohit Bhandari is the Chair of the Department of Surgery at McMaster University.

AT, JWB and RS report no competing interests.

# 3.5 Appendices

## *3.5.1 Appendix A1: Statistical Analysis Plan*

| Objective | Outcome Measure | Explanatory Variables | Hypothesis | Method of Analysis |
|---|---|---|---|---|
| **1) Primary** | | | | |
| To estimate the level and nature of divergent thinking ability among surgeons | Abbreviated Torrance Test for Adults (ATTA) creative ability score<br><br>ATTA sub scores:<br>- Fluency<br>- Originality<br>- Elaboration<br>- Flexibility | N/A | N/A | Descriptive Analysis<br>- Mean (95% confidence intervals [CIs]) |
| **2) Secondary** | | | | |
| To determine estimate the level of creative self efficacy among surgeons | Creative self-efficacy<br>- 7-point Likert scale | N/A | N/A | Descriptive Analysis<br>- Mean (95% CI) |
| To determine the association between divergent thinking and sociodemographic, professional, and lifestyle characteristics | Abbreviated Torrance Test for Adults (ATTA) creative ability score | Age; sexual identity; years of surgical training; creative self-efficacy; undergraduate degree; hours spent alone | The explanatory variables will be associated with ATTA creative ability scores | Multiple linear regression |

| | | | | |
|---|---|---|---|---|
| | | per week; hours of work per week; research output (# of published peer-reviewed papers) | | |
| **3) Sensitivity Analyses** | | | | |
| To assess whether there is a clustering effect at the level of surgical specialty | Abbreviated Torrance Test for Adults (ATTA) creative ability score | Age; sexual identity; surgical specialty; years of surgical training; creative self-efficacy; undergraduate degree; hours spent alone per week; hours of work per week; research output (# of published peer-reviewed papers) | There is a clustering effect at the level of surgical specialty | Multiple linear regression<br>- Mixed effects model, with surgical specialty at as a random effect |

# Chapter 4

## An Investigation of DivErgent Thinking Among Surgeons (IDEAS): A Cross-Sectional Survey

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# Abstract

*Background*

Creativity is considered an essential competency in the 21st century. This is particularly the case in surgery, where creativity is imperative for innovation and clinical problem-solving. Nonetheless, there has been limited research on creativity in surgery, as evidenced by the scarcity of the literature on the topic. Using a measure of divergent thinking ability, a cognitive process implicated in creative ability and problem-solving and a predictor of creative achievement, we aimed to explore the creative potential of surgeons.

*Objectives*

The primary objective of this survey was to determine the levels of divergent thinking ability in surgery. The secondary objectives were to explore factors associated with divergent thinking, assess self-reported confidence in creative problem-solving and the effect of the surgical profession on creative potential, and gain some insights into the manifestation of creativity in surgery.

*Methods*

We administered a survey of divergent thinking in surgeons and surgeon trainees using a validated test of divergent thinking. The Abbreviated Torrance Test for Adults (ATTA) measures divergent thinking across 4 domains (fluency; originality; elaboration; flexibility). We asked the surgeons to self-report their confidence in creative problem-solving and the effect of the surgical profession on creative potential using 7-point Likert

scales. We also performed a regression analysis to identify factors associated with divergent thinking and conducted semi-structured interviews with outlier high-scoring participants.

*Results*

Eighty-two surgeons and surgeon trainees were surveyed from the McMaster University Medical Center. The mean participant age was 29.41 (standard deviation [SD] 6.52), 51.2% of whom were female. Participants demonstrated an average level of divergent thinking ability (62.39 [95% confidence interval (CI): 61.25, 63.53]), which was not meaningfully different compared to the mean adult normative score of 60 (SD 7.87). While participants scored significantly higher than the average adult on fluency and flexibility (p<0.001 for both), the mean score for originality was significantly lower (p<0.001). Our regression found being female to be positively associated with divergent thinking (estimated $\beta$ = -3.58 [95% CI: -6.25, -0.90], p=0.010), while a marginally significant, negative association between divergent thinking and surgical experience (2+ years) was observed (estimated $\beta$ = -2.53 [95% CI: -0.41, 5.46], p=0.090).

*Conclusion*

Overall, divergent thinking test scores among surgeons and trainees are similar to adult norms; however, surgeons and trainees scored significantly lower in originality, but higher in fluency and flexibility. Our findings suggest need for further exploration of creative thinking in surgery.

## Key Summary

- Creativity is an essential for clinical problem solving, fuels innovation, and can improve well-being. Yet, there is a lack of literature researching creativity among surgeons.
- Surgeons demonstrated an average level of divergent thinking ability, a key component of individual creativity and measure of creative potential.
- While fluency and flexibility were significantly higher than average, surgeons demonstrated a significantly lower level of originality vs. the average adult.
- Being female had a significant positive association with divergent thinking. Harnessing the creative potential of women, through increased representation and equal opportunity for participation in surgical innovation, is essential.
- Surgical training had marginally significant negative association with divergent thinking. The effect of apprenticeship model-based surgical training on the process of creative idea production could explain the low levels of originality observed.

## 4.1 Introduction

Creativity is increasingly acknowledged as one of the core competencies in the 21st century [1-3]. In medicine, physicians have highlighted the need to nurture and encourage creativity to tackle complex challenges facing modern medicine [4, 5]. The production of novel, useful and perceptible products through the interaction of aptitude, process, and environment [6] can have profound effects on society, particularly in the field of medicine. Creativity manifests in clinical problem-solving [7], and on a personal level, people who are more creative demonstrate higher levels of well-being and may even live longer [8, 9].

Consequently, creativity is a particularly relevant and important ability in medicine, influencing patient care and the lives of physicians themselves.

At the surface, surgery may not seem like a creative endeavour. Surgery is a high-stakes profession: guidelines, evidence-based decision pathways, and a training process characterized by demonstration, imitation, and repetition are some of the many ways that surgeons attempt to standardize processes in the operating room. Theoretically, creativity involves taking risks and experimenting with novel ideas, whilst standardization seeks to minimize variance to achieve consistency in outcomes [10]. Moreover, experiencing uncertainty – a common state for surgeons – can lead to negative bias towards creativity, impeding the ability to be creative [10]. This suggests that creativity is not desirable in surgery. However, the extrinsic and intrinsic value of creativity in the surgical profession is apparent. Whether it be the development of a new intraoperative techniques or the ideation of an effective, novel solution in the operating room for a rapidly deteriorating patient, creativity has utility for both patients and surgeons alike [11, 12].

JP Guilford, a pioneer in the scientific study of creativity [13], introduced the concept of divergent thinking, defined as the generation of a variety of ideas and solutions to a given problem [14]. Divergent thinking is a cognitive ability and component of creativity [15]. Divergent thinking tests, like the Torrance Test of Creative Thinking (TTCT) [16], are among the most widely utilized tests of creativity, and have demonstrated a strong ability to predict creative achievement up to 40 years after administration [17-19]. Furthermore, associations between divergent thinking and creative problem-solving and performance have been identified [20, 21]. Thus, surgeons with high levels of divergent thinking ability

may be better equipped to generate novel solutions and ideate original techniques or technologies, subsequently providing better outcomes for patients.

To our knowledge, no studies of divergent thinking have been performed among surgeons. Given the value of divergent thinking, and creativity at large, for surgeons, we sought to fill this gap by conducting a survey of divergent thinking ability. Given the above average intellectual abilities of those who study medicine [22, 23] and the association of general intelligence with divergent thinking [24], we hypothesized that the divergent thinking ability of surgeons would be higher than average compared to the average adult, as measured by a validated tool [25].

*Objectives*

We aimed to conduct a cross-sectional survey to meet our primary objective of exploring divergent thinking ability in surgery at our surgical department at McMaster University (Hamilton, Canada). As secondary objectives, we sought to explore factors associated with divergent thinking, assess self-reported confidence in creative problem-solving and the perceived effect of the surgical profession on creative potential, and gain insights into the manifestation of creativity in surgery.

## 4.2 Methodology

We followed the Consensus-Based Checklist for Reporting of Survey Studies (CROSS) for the reporting our survey [26], and published our protocol [27]. The Hamilton Integrated

Research Ethics Board Ethics provided approval for this research project (Project #15178).

### *4.2.1 Study Population*

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

### *4.2.2 The Survey*

The ATTA [25] is an assessment tool of divergent thinking ability and an abbreviated version of the Torrance Tests of Creative Thinking (TTCT) [28], the most utilized creativity assessment tool [29] which has been found to be a valid predictor of creative and personal achievement up to 50 years after testing [17-19, 30]. The ATTA test has been validated as a predictor of creative performance in an adult population [31]. The ATTA test is a 3 part-test that measures 4 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). The first activity was a verbal task involving the generation of responses to a given prompt; activities 2 and 3 were figural

tasks involving drawing to complete incomplete figures. Each task was time-limited to 3 minutes.

### *4.2.3 Administration*

Following consent, a baseline characteristics form was completed by the participants. Collected information included: age; sex; years of post-graduate surgical experience; surgical specialty; relationship status; background/ethnicity; undergraduate degree; time spent alone each day; hours worked per week; the presence or absence of creative hobbies or creative friends (as defined by the participant); whether the participant holds a leadership position (division head; program director); whether the participant regularly makes time to reflect or think; and the number of peer-reviewed publications. After completion of the participant characteristics form, a study coordinator (AT or TM) educated on the testing protocol administered the Abbreviated Torrance Test for Adults (ATTA) [25] in person to ensure proper adherence to protocol.

### *4.2.4 Statistical Analysis*

In order to estimate the average total ATTA score using a 95% confidence interval (CI) with a margin of error of two and a total ATTA score standard deviation (SD) of 7.87 [32], we calculated the minimum sample size to be 60 participants, which our sampling strategy ensured. However, we managed to get responses from 82 participants.

Upon test completion, we assessed participant responses according to the ATTA manual and calculated a total scaled ATTA score – the sum of each scaled sub-score – for each

surgeon, normalized to an adult population during the standardisation sampling process [32]. The average adult's normative total ATTA score was 60 (SD 7.87), representing the middle 20% of adults. Each sub-score had an average score of 15 (range 11-19). Sub-scores between 11-13 and 17-19 were considered below-average and above-average, respectively. The ATTA has high interrater reliability (0.95-0.99) and a Kuder-Richardson 21 (KR21) reliability coefficient of 0.90 [32], indicating high test reliability [32]. All tests were assessed independently by one reviewer trained on the ATTA assessment tool. A second reviewer was recruited to the study team (VA) and trained on the ATTA assessment tool to assess all tests independently, for the testing of score reliability. We calculated the intraclass correlation coefficient (ICC) between reviewers using a two-way mixed model, testing for absolute agreement.

We used the following statement to assess creative self-efficacy, 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 surgeon's belief that their work enhances 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, with bins 2 to 3 and 5 to 6 being collapsed.

After recruitment and grading of all tests, we conducted two semi-structured interviews with two outlier high-scoring participants to gain further insights into the intersection of creativity and surgery. The participants were invited to meet over Zoom with the researcher. Each interview lasted roughly 40 minutes and began with a history of the

participant's medical background and current position. A thematic, semi-structured interview guide was used in both interviews, covering the following themes: 1) the definition of creativity, 2) the effect of medical school and residency on creativity, 3) the manifestation and value of creativity in surgery, 4) the impact of creative hobbies and friends on a surgeon. Interviews were recorded via Zoom and transcribed verbatim manually. A thematic analysis of the interviews using ground theory [33] was conducted by a single assessor: as the interviews were read, codes were generated and overlapping themes were identified.

We used descriptive statistics to analyse the demographics of the respondents. We reported continuous variables as mean (SD) when normally distributed, or median (range) when not normally distributed, and count (percent) for categorical variables. We used descriptive analyses (reported as mean scores with corresponding 95% CIs) for the total ATTA scores overall and by baseline factors. The scores for the total ATTA score and the 4 scaled sub-scores were graphically displayed using forest plots, and the distribution was illustrated using violin plots created with SRPlot [34]. Minimally important differences (MIDs) were estimated for the total ATTA score by using half the standard deviation as a threshold for MID [35]: thus, total ATTA scores greater than 64 and less than 56 were considered an important difference relative to the average adult score of 60 (SD 7.87). We also conducted two-sided, one-sample t-tests for the total ATTA score and each sub-score compared to the average adult score/sub-score.

With a minimum sample size of 60, our linear regression was powered to include up to 30 variables [36]. We performed a multiple linear regression to explore factors associated

with divergent thinking ability using the following variables: age, years of surgical experience, sex, research output (measured by the number of publications), the presence of creative hobbies and friends, surgical specialty (general surgery vs. other), time spent alone per day, hours worked per week, and confidence in creative problem-solving ability (confident vs. neutral or not confident). We sought to explore the association between sex and divergent thinking, as existing literature suggests a difference in divergent thinking between males and females [37-42]. 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 doing residual analysis. As a sensitivity analysis, we reperformed the regression analysis treating the surgical specialty as a random effect to account for potential clustering or similarity of scores among participants within specialties. All statistical analyses were performed using SPSS 28.0 [43], and all bar graphs and forest plots were built in Microsoft Excel.

## 4.3 Results

For the total ATTA scores, the ICC between the two reviewers was 0.922 (95% CI: 0.878, 0.949) indicating excellent reliability [44].

### *4.3.1 Respondent Characteristics*

A total of 82 surgeons and surgeon trainees completed the survey. The average age was 29.41 (SD 6.52) years. Surgical experience varied widely, with a median of 2 years (range: 0-30) of surgical 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**.

### *4.3.2 Creative Self-Perception*

Whilst 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**).

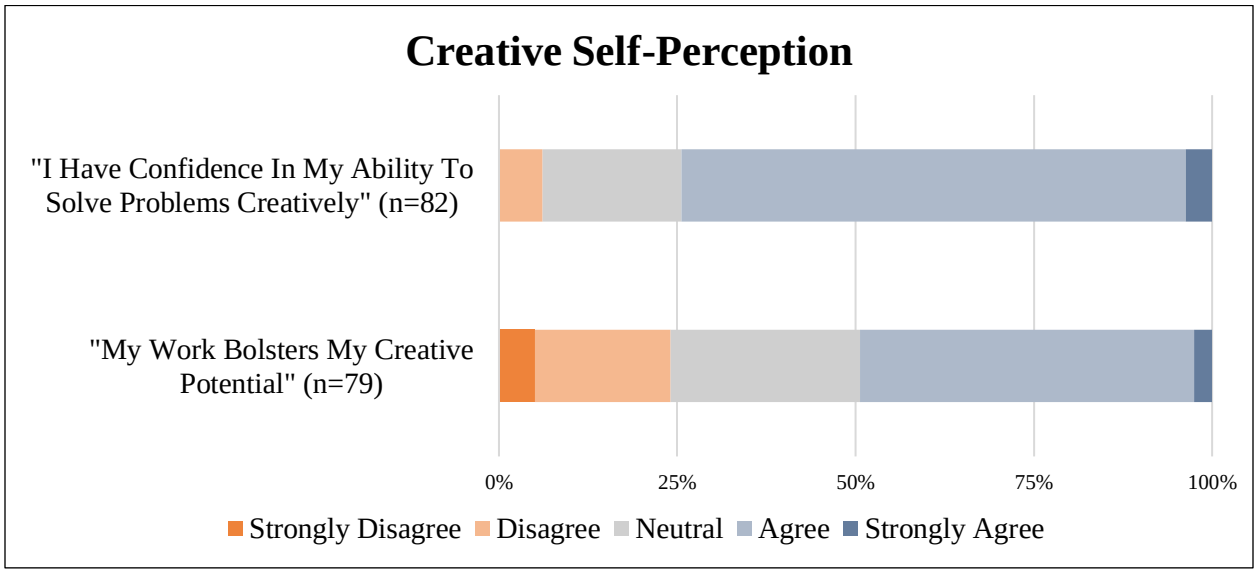


**Figure 1**: *Likert Responses for Confidence in Creative Problem-Solving and Effect of Surgical Profession on Creative Potential*

### *4.3.3 Overall Creativity Scores*

Overall, the average total ATTA score across all participants was similar to the average adult score of 60 (SD 7.87), with a mean score of 62.39 [95% CI: 61.25, 63.53] (**Figure 2**). No important differences were observed between the average adult scores and the overall ATTA scores or total ATTA score by baseline factor (**Figure 2**).

The participants scored significantly higher scores 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]) (**Figure 3**; $p<0.001$ for both). However, originality scores (13.73 [95% CI: 13.29, 14.17]) were significantly lower than the average adult (**Figure 3;** $p<0.001$). 40 participants (48.8%) scored in the bottom 23% of adults for originality (score of 11-13). Elaboration scores (the ability to embellish ideas with details; 15.41 [95% CI: 14.92, 15.91]) were not significantly different vs. the average adult (**Figure 3;** $p=0.097$).

The distributions of the total ATTA scores and each sub-score are displayed with violin plots (**Appendix 1 and 2**).

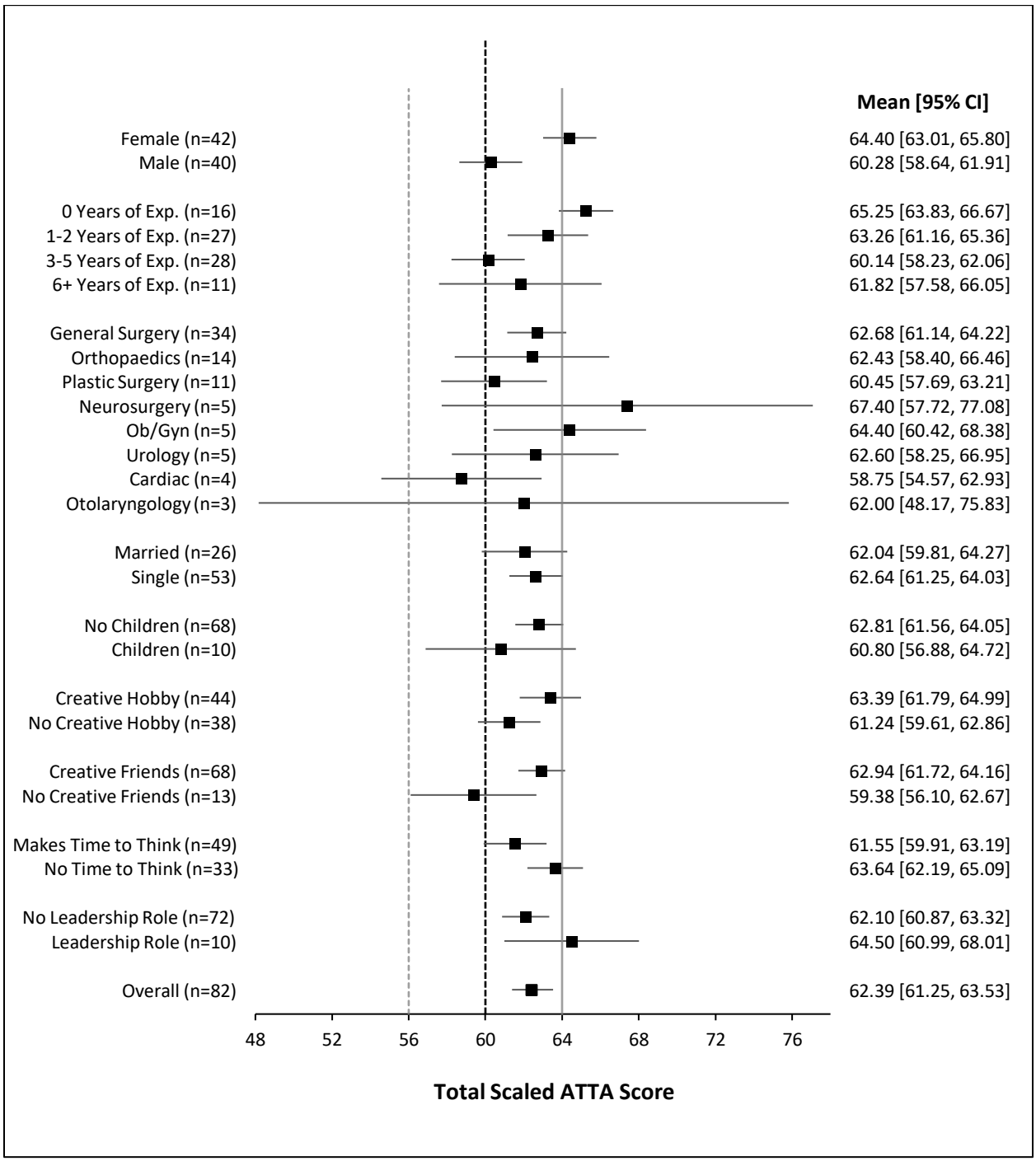


**Figure 2**: *Estimated total ATTA scores by baseline factor. The adult normative score of 60 and estimated thresholds for minimally important differences are labeled with black and dotted lines, respectively.*

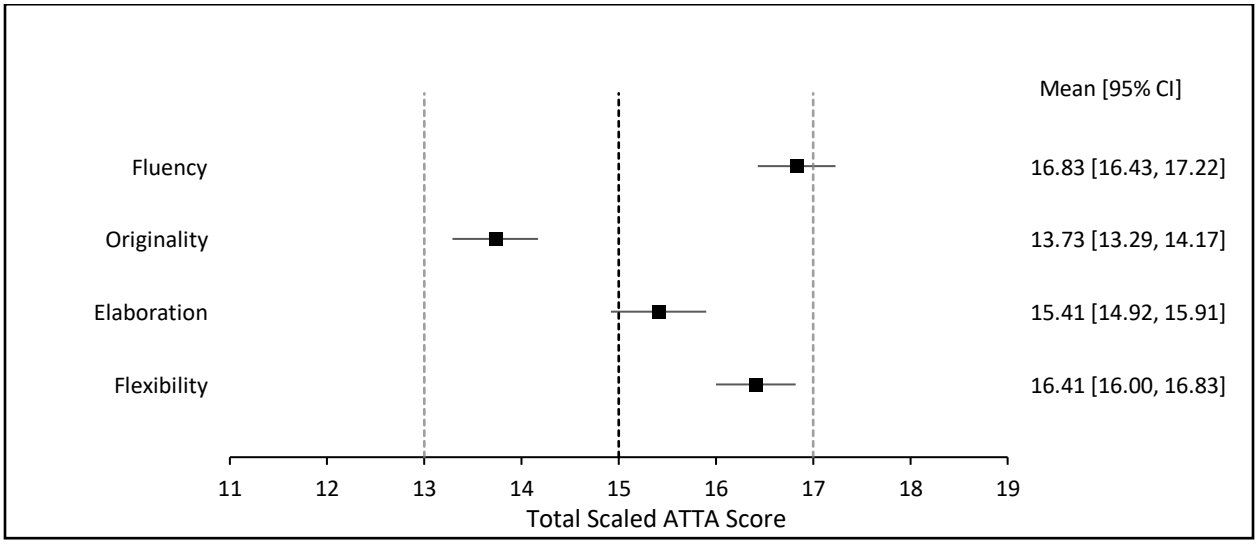


**Figure 3**: *Estimated ATTA sub-scores for fluency, originality, elaboration, and flexibility (n=82). The adult normative score of 15 and the thresholds for below- and above-average scores are labelled with black and grey dotted lines, respectively.*

### *4.3.4 Subgroup Effects*

Being male had a significant negative association with divergent thinking ability (estimated β = -3.58 [95% CI: -6.25, -0.90], p<0.001). Having less than 2 years of surgical experience was marginally significantly associated with divergent thinking (estimated β = 2.53 [95% CI: -0.41, 5.46], p=0.090). Age, creative hobbies, creative friends, specializing in general surgery, number of publications, confidence in creative problem-solving ability, time alone per week, and hours worked per week were not associated with divergent thinking (**Table 2**). The sensitivity analysis treating surgical specialty as a random effect yielded similar results (**Table 3**).

### *4.3.5 Semi-Structured Interviews*

The two surgeon trainees interviewed came from musical backgrounds and were in the first two years of their surgical training. Surgeon 1 (S1) specialized in neurosurgery and Surgeon 2 (S2) specialized in orthopaedics.

S1 commented on the effect of medical school and residency training on their creativity, indicating that medical training may be stifling creative thinking.

> *I think that side of me has been stifled a little bit as I have gone through medical school and into residency. I find that 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 really don't like that. But 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 a little bit. (S1)*

These findings are corroborated by the results of the creativity test, as lower divergent thinking scores were observed in surgeons with more surgical experience.

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

> *It's combination of technical mastery of a certain skill set, but also flexible thinking relating to how surgery is different every time. No one can teach you how to solve every problem or perform every surgery. All you can do is build your skills and then build your thinking. I don't really think that 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, surprisingly, sometimes takes more creativity than you would think. (S2)*

Both surgeon trainees stressed the importance of developing problem-solving skills by 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)*

> *We start to take solo calls overnight after the first few months. One thing that benefited me was overnight, when you run into issues, you're encouraged to figure it out. Obviously, if there is a safety concern that is different, but there are a lot of little decisions you can make like if you admit someone who doesn't need to be admitted, you can always fix it in the morning. Being encouraged to make those decisions and figure those things out on my own, as an R1 (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 alive. (S1)*

Both surgeon trainees said that having creative hobbies is an important outlet for the surgeon.

> *It balances the 'non-playing' aspect of surgery because obviously there's part of that which is important. I think that it can help with things like stress and burnout. (S1)*

> *I think its 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)*

## 4.4 Discussion

While overall divergent thinking ability was average, we found that surgeons and surgeon trainees displayed significantly higher levels of fluency and flexibility and lower levels of originality compared to the average adult. Females scored significantly higher on the test the males, and though not significant, having less than 2 years of training and having creative friends trended towards a positive association with divergent thinking. Age, number of publications, hours worked per week, and time spent alone per day had no association with divergent thinking. The semi-structured interviews corroborated several of the findings in the survey, with one interviewee suggesting creativity was being 'stifled' in medical training and that having imaginative people in one's life can maintain creativity.

Prior to conducting this study, we found only 3 studies on creativity in surgery, two of which were citation analyses performed over 30 years ago [45, 46], and one cross-sectional study on burnout which included mostly non-physicians [47]. This makes our survey is the first-ever assessment of creativity in surgeons and surgeon trainees. We recruited over 80 participants, which was well beyond the minimum sample size determined by our power calculation. Moreover, we collected sociodemographic and professional characteristics, enabling us to perform sub-group analyses and regression analyses to identify trends and factors associated with divergent thinking ability. We supported the survey with self-assessments of confidence in creative problem-solving and the impact of the surgical profession on creative potential, as well as interviews with high-scoring surgeons. This contextualized the results and allowed us to corroborate the findings in our survey: for example, the negative trend in divergent thinking scores by years of surgical experience was echoed by an interviewee reporting a stifling of creativity in surgical training, as well as the lack of self-perceived benefit of the surgical profession on one's creative potential.

Our results are consistent with the results of several studies which have found women to significantly outperform men on creativity tests [37-42], particularly as women reach higher education [39, 41]; however, contrasting evidence finding no difference between men and women on divergent thinking ability has also been reported [48-50]. Despite increases in representation in recent years, surgery is a male-dominated profession [51, 52]; the lack of women in surgery may be limiting the creative potential of the field. The gender gap in invention is well established, with women in the sciences inventing and

patenting at significantly lower rates than men [53-55]. Harnessing the creative potential of women in surgery would benefit the entire profession and the patients they care for. Addressing barriers to entry for women entering surgery, such as mitigating gender discrimination [56, 57] and creating equal opportunity for participation in surgical innovation, are important steps to cultivate the creativity of women in surgery.

We found a marginally significant, negative association (p=0.090) between 2 or more years of surgical experience and divergent thinking, controlled for age and other factors, suggesting that surgical training may be dampening divergent thinking ability. This was corroborated by our interviews, where a 'stifling' of creativity by the medical/residency training process was reported. Surgery is a high-stakes profession: because of the elevated risk and uncertainty, the surgical training process, based on an apprenticeship model [58], places a strong emphasis on following standards and instructions in the operating room. Particularly in novice trainees, original, uncommon ideas not steeped in the necessary domain-expertise may feel too risky to suggest in the operating room. Over time, the apprenticeship model often employed in surgical training – teaching by demonstration, emulation, and repetition -- may be leading to an erosion of divergent thinking capability, as trainees inadvertently learn that, to become a safe and effective surgeon, they must put their original ideas to the side and 'do as I do'. While creative decision-making is often not relied upon in high-pressure environments, there are instances in which this ability is necessary [59]. In high-pressure professions like aviation, which are equally as standardized, the importance of creativity becomes apparent in emergency situations, such as the Hudson River landing in 2009. Similarly, in surgery, operations do not go always go exactly according to plan. In emergency situations,

creative decision-making can become essential, and the stifling of creativity may become evident. Thus, introducing 'controlled creativity' into surgery, as opposed to strictly following the apprenticeship model should be considered and studied in the future.

Divergent thinking is correlated to broad retrieval ability and processing speed [24], or more broadly, intelligence [60, 61]. Surgeons, and physicians at large, are often selected based on general intelligence, as measured by academic performance and standardized test scores [62, 63]. This explains the high fluency and flexibility scores observed – their intellectual prowess facilitates the generation of large numbers of responses. But, given the high correlation between fluency, flexibility, and originality [64-67], we would therefore expect to observe similarly high levels of originality. This was not the case. Finding significantly below-average levels of originality where higher levels are expected could be explained by the surgical training process. The originality, or creativeness, of the idea is related to the remoteness of the elements that constitute the idea; the ability to generate original solutions decreases as one gains experience solving problems in a certain fashion [68]. Thus, training surgeons to solve clinical problems according to standards and instructions may prevent them from engaging in divergent, associative thinking using remote elements, thus eroding their ability to generate original ideas. Developing programs to foster creative ideation in surgery could help surgeons improve their ability to generate novel, effective ideas.

This study has limitations. We chose an abbreviated version of the more comprehensive Torrance Test of Creative Thinking, which requires 30-45 minutes to complete. While the ATTA has never been used in a surgical population, it has shown good predictive validity

of creative achievement in an adult population [31]. Further, it's 10-minute administration time greatly improved compliance, study feasibility, and recruitment of participants. Secondly, grading of the tests was performed by one reviewer. To test the reliability of our results, we identified a second grader to mark the tests independently. The high level of agreement between the two reviewers (ICC=0.922) gives us a great degree of confidence in the test scores. A third limitation was the limited sample size in several of the surgical specialties. Unfortunately, despite our efforts, it was not possible to recruit more participants in several of the surgical specialties, which affected the precision of our estimates and our subsequent ability to make conclusions on divergent thinking ability within surgical specialties. We plan to conduct a larger study adequately power us for more precise assessment of divergent thinking by sub-specialty. Fourthly, we only interviewed two participants, both of whom were selectively sampled, which likely did not allow for data saturation. However, the purpose of the qualitative component was to provide additional insights to aid in the contextualization of the results, and not to obtain fully elaborated perspectives on creativity. Fifth, given the cross-sectional, observational nature of the survey, we cannot determine causation or control for residual confounding from variables we did not collect. Finally, the measurement of divergent thinking may have been influenced by motivational factors, which could affect test performance [69].

*Conclusions*

We observed levels of divergent thinking test scores among surgeons and trainees that was not meaningfully different to the average adult. however, surgeons and trainees scored significantly lower in originality, but higher in fluency and flexibility. Score

significantly higher on the test, and a negative trend between divergent thinking and surgical experience was observed. We hypothesize that the observed low levels of originality may be a result of the negative effect of surgical training on the process of original idea production. Interventions, new training methods, and environmental changes could improve divergent thinking in surgeons and subsequently improve outcomes for patients and surgeons alike. Future studies exploring how divergent thinking is used in surgery, levels of convergent thinking, and the underlying mechanism of effect that surgical training has on divergent thinking are of interest.

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**Conflicts of Interest**

AT, VA, 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.

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**Abbreviations**

ATTA – Abbreviated Torrance Test for Adults

CROSS – Consensus-Based Checklist for Reporting of Survey Studies

ICC – Intraclass Correlation Coefficient

MTCA – Minimal Theory of Creative Ability

TTCT – Torrance Test for Creative Thinking

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# 4.6 Tables

## *4.6.1 Table 1: Baseline Characteristics*

| **Baseline Characteristics** | **n = 82** |
|---|---|
| Age (years) | 29.41 (6.52) |
| 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%) |
| Gen. Surgery | 34 (41.5%) |
| Neurosurgery | 5 (6.1%) |
| Obstetrics & Gynecology | 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%) |
| 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 (%)*

### *4.6.2 Table 2: Multiple Linear Regression Results – Predictors of Total ATTA Score*

| Variable | | Estimated β 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. | |
| | Gen 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 |

*CI: confidence interval; ATTA: Abbreviated Torrance Test for Adults*

### *4.6.3 Table 3: Mixed Model Linear Regression Results – with Specialty as a Random Effect*

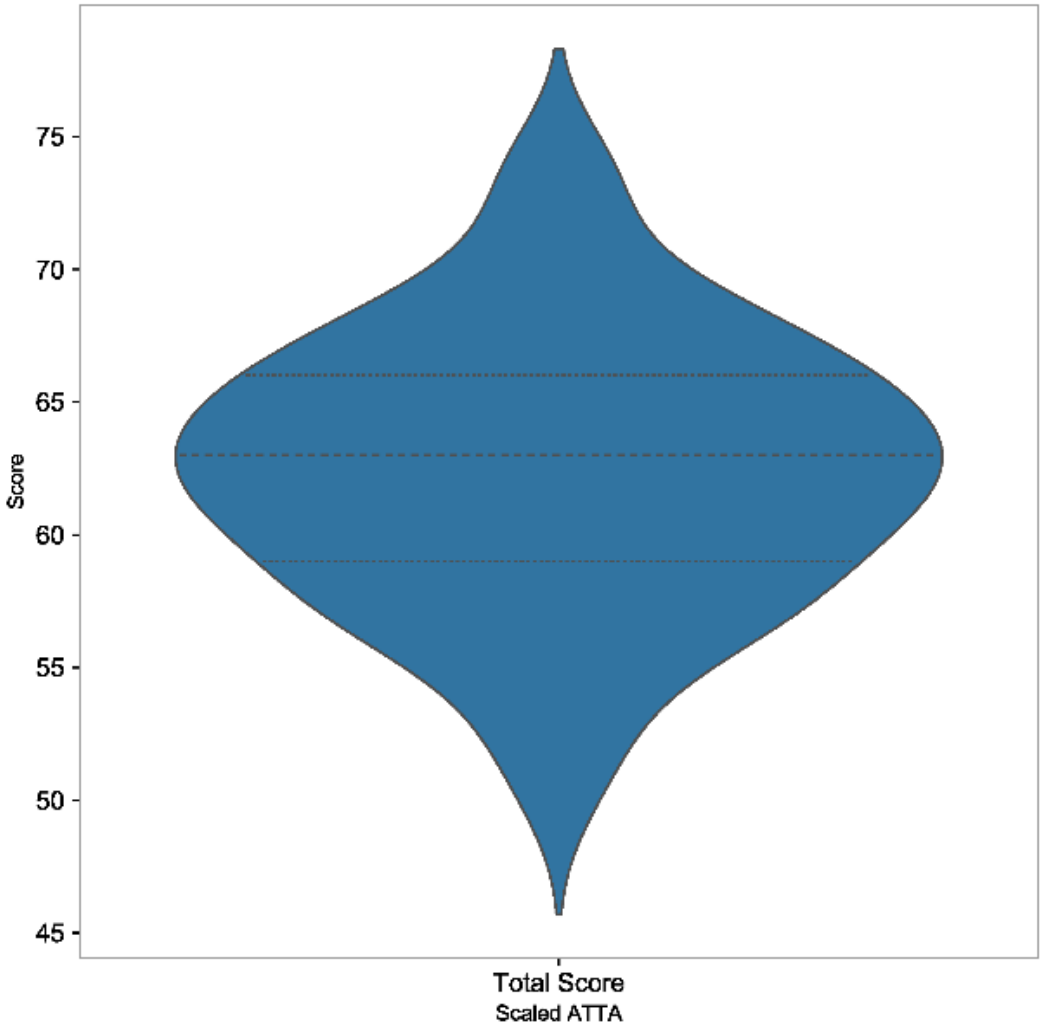
| Variable | | Estimated β coefficient (95% CI) | p-value |
|---|---|---|---|
| Age | | 0.06 (-0.22, 0.35) | 0.658 |
| Surgical Experience | 2+ Years | Ref. | |
| | Less Than 2 Years | 2.09 (-0.84, 5.01) | 0.158 |

| | | | |
|---|---|---|---|
| Sex | Female | Ref. | |
| | Male | -3.70 (-6.33, -1.06) | 0.007 |
| Creative Hobby | No Creative Hobby | Ref. | |
| | Has Creative Hobby | 0.24 (-2.14, 2.62) | 0.843 |
| Creative Friends | No Creative Friends | Ref. | |
| | Creative Friends | 2.27 (-0.90, 5.43) | 0.157 |
| Creative Problem Solving | Not Confident or Neutral | Ref. | |
| | 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 |

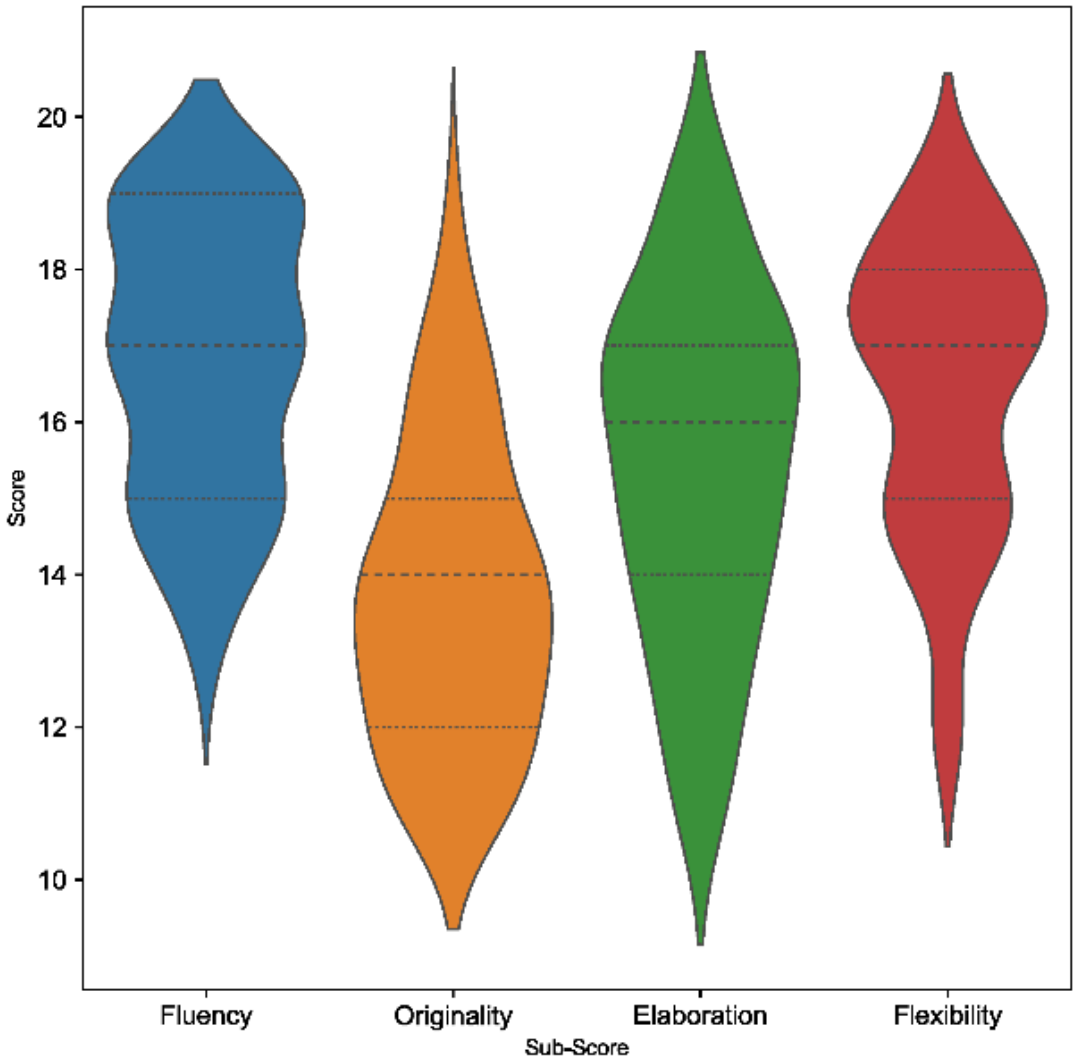
*CI: confidence interval*

# 4,7 Appendices

## *4.7.1 Appendix 1: Violin Plots for Total ATTA score*



### *4.7.2 Appendix 2: Violin Plots for ATTA Sub-scores*




### *4.7.3 Appendix 3: T-tests for Sub-scores vs. Average Adult Score (15)*

| Variable | *t* | *df* | 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*

# Chapter 5

## Conclusion

This thesis is an exploration of creativity in surgery. The first chapter provides a background on the scientific study of creativity, including the current theories and measurement tools for creativity, the connection between creativity and innovation, and role of both in surgery. The second chapter contains the results of a scoping review on creativity research in medicine, which identified lack of research in the area, particularly in the field of surgery. The third chapter contains the published protocol for a survey of divergent thinking in surgeons, with the results of the study reported in chapter four. This final chapter provides an overview of each chapter and the subsequent implications of the results.

# 5.1 Summary of Thesis

## *5.1.1 Chapter One: Introduction*

Empirical research on creativity began in the 1950s. A rise in interest in the nature and manifestation of creativity followed: a range of theories on creativity, as well as a host of measurement tools, such as the Torrance Test of Creative Thinking (TTCT), have been developed over the years to facilitate the assessment of creative ability and potential. The field of surgery has benefited greatly from the creative thinking of physicians and scientists, who have continually found new methods, techniques, and solutions that improve patient outcomes and advance the surgical craft. For example, the rise of endoscopy, combining advances in various sectors from electronics to computing, has revolutionized the way many surgeries are performed. Yet, surgery is often not viewed as a creative endeavour; the regimented nature of medical school and surgical training may not lend to creative thought. There is a need to understand the role and importance of creativity and surgery at a deeper level; an exploration of creativity in surgeons could act as the first step towards improving and cultivating creativity in surgery.

## *5.1.2 Chapter Two: State, Trends & Distribution of Creativity Research in Medicine: A Scoping Review*

**Key Findings**: Upon searching the PubMed, EMBASE, and PsycINFO databases up to 14 March 2023, fifty-four primary research studies on creativity in medicine (physicians & nurses) were identified. 53% of studies were cross-sectional in nature, and 80% of studies were published in the last 10 years. Studies in the field of nursing consisted 73%

of all studies, primarily driven by the efforts of a small group of researchers in Taiwan. Areas of inquiring included improving creativity skills, the role of creativity in medicine, and the relationship between creativity in burnout. Over 30 different tools were used, the most common being the TTCT (n=6). Limited primary research on creativity exists.

**Limitations**: This study was limited by the exclusion of studies not published in English and unpublished abstracts, which may have increased the risk of publication bias. However, we excluded only 1 study during full-text review due to not being published in English; we also performed an extensive database search combined with the use of a citation platform that identifies similar articles based on overlapping citations and references, which resulted in a robust search strategy, minimizing the risk of publication bias.

**Future Directions**: The results of this scoping review signal the need for more research on creativity in medicine, particularly in the field of surgery. Studies exploring the level and importance of creativity in physicians, as well as the development of medicine-specific creativity assessment tools, could be starting points.

### *5.1.3 Chapter Three: Investigating Divergent Thinking and Creative Ability in Surgeons (IDEAS) – A Survey Protocol*

**Methods & Analysis**: We have planned a survey of divergent thinking ability in surgeons at the McMaster University Department of Surgery. We will perform convenience sampling of surgeons in the Department, with a priority on diversity in age, background, level of training and surgical specialty. To assess surgeons, we will use the Abbreviated Torrance Test for Adults (ATTA), a shortened version of the TTCT, which

measures 4 norm-referenced abilities: fluency, originality, elaboration, and flexibility. Our sample size calculation indicates a minimum requirement of 60 participants. Descriptive statistical analysis and multiple linear regression analysis are planned to explore creative ability overall and by sub-population, as well as identify potential factors associated with divergent thinking ability.

**Strengths & Limitations**: Our study is strengthened by sampling strategy favouring diversity and heterogeneity in participant characteristics, the use of an objective and validated test of divergent thinking, and the collection of sociodemographic, lifestyle, and professional variables that will be used to explore factors associated with divergent thinking ability. This study design is limited by the convenience sampling strategy, which may lead to an inaccurate representation of divergent thinking ability in surgeons or surgical disciplines, as well as the use of an abbreviated tool where a more comprehensive tool exists. However, the choice of tool was a pragmatic decision due to the high time-cost of the full tool (45 minutes) vs. the abbreviated version (10 minutes).

### *5.1.4 Chapter Four: An Investigation of DivErgent Thinking Among Surgeons (IDEAS): A Cross-Sectional Survey*

**Key Findings:** Eight-two surgeons participated in the survey. Surgeons displayed an average level of divergent thinking ability relative to the general adult population. However, surgeons demonstrated below-average ability to generate original responses. Being male was significantly negatively associated with divergent thinking. Surgical experience trended towards a negative association with divergent thinking; interviews

with high-scoring surgeons suggested a stifling a creativity within the medical training process, which is corroborated by the results of our survey.

**Limitations**: This study was limited by the choice of test, the ATTA, where a more comprehensive test exists. However, this tool has been validated as a predictor of creative achievement in an adult population and was also chosen for pragmatic reasons given the time-constraints placed on our target population. Secondly, the cross-sectional nature of the survey prevents the determination of causation with respect to factors associated with divergent thinking. We plan to perform a follow-up study in the sample population to assess the evolution of divergent thinking and assess causation in the identified factors associated with divergent thinking.

**Future Directions**: This study opens the door for several studies in the future using a variety of methodological designs. A larger, multinational study of creativity in medical professionals may identify additional modifiable factors that facilitate or inhibit creativity. A study exploring the association between creativity and improved patient outcomes and physician-related outcomes is essential to establishing the importance of creativity in medicine. Subsequently, the development of an intervention or program to improve creativity in medical professionals, tested through a randomized controlled trial, to improve creativity and clinical outcomes is of interest.

## 5.2 Implications

This thesis highlighted the lack of literature on the topic, explored the current state of divergent thinking in surgeons, illuminated the importance of creativity in medicine, and identified factors associated with divergent thinking ability. Subsequently, it serves as the

foundation for future research in the area to establishing the clinical importance of creativity in surgery. Several avenues of research have been illuminated in light of these findings: qualitative studies with surgeons, larger surveys of creativity, explorations into team creativity in the medical setting, and the benefits of creativity and creative hobbies for the patient and physician are all interesting ideas requiring investigation. The world of creativity in medicine, and the opportunity presented by the dearth of literature on the topic, has been opened by this thesis.