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## Stereotype Threat and Working Memory among Surgical Residents

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### Abstract

**Background:** Stereotype threat is a situational threat in which a member of a stereotyped group fears conforming to a negative stereotype. In this study, we examined the impact of stereotype threat on surgical performance and working memory among surgical residents.

**Methods:** Residents at one institution were randomized to either the threat condition or the no-threat condition. We administered the Vandenberg Mental Rotation Test and the reading span task to assess residents' mental rotation and working memory, respectively.

**Results:** 102 residents participated in this study (response rate 61%). In multivariable analysis, we found gender differences. Men outperformed women in mental rotation, and women outperformed men in working memory. There was no effect of condition on performance on the mental rotation or working memory test.

**Conclusions:** No effect of condition on either test suggests that high-achieving women may be less susceptible to stereotype threat. This could be due to self-selection or adapted resilience, or women in this context may be more qualified to reach the same level of achievement as their male colleagues.

### Table of Contents Summary

This study examined the impact of stereotype threat on surgical performance and working memory among surgical residents. Residents were randomized to a stereotype threat condition or a no-threat condition. We found gender differences in both mental rotation ability, such that men outperformed women, and in working memory, such that women outperformed men. There was no significant impact on women's performance in the threat condition.

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## Keywords

resident; gender; working memory; stereotype threat; mental rotation

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## Introduction

While roughly 50% of medical students are women,<sup>1</sup> only 36% of surgical residents are women.<sup>2</sup> Furthermore, only 25% of surgical faculty members are women.<sup>3</sup> Although various factors contribute to the lesser representation of women within surgery, stereotype threat is likely one of these factors.<sup>4,5</sup> Stereotype threat is a situational threat in which a member of a stereotyped group fears being reduced to the stereotype or conforming to the stereotype.<sup>6</sup> Exposure to stereotype threat has been shown to decrease performance in domains that a person cares about. Research has demonstrated this phenomenon in many situations, including women completing mathematics problems,<sup>7</sup> white men performing athletic tasks,<sup>8</sup> and African-Americans taking intelligence tests.<sup>9,10</sup> In medicine there is a negative stereotype that women are inferior surgeons compared to men. Research has shown that surgical residents of both genders perceive that the general public, faculty, and other residents believe that men are better surgeons than women.<sup>4</sup> Due to the presence of this stereotype, women, and not men, are expected to experience stereotype threat in situations where they are made aware of the stereotype. This could occur simply from being in an environment with significantly more men than women, as is the case in surgical training.

It has been proposed that stereotype threat decreases performance by decreasing working memory.<sup>11</sup> For example, women who identify with math and take pride in their math ability may occupy some of their computing power with thoughts related to proving their ability rather than the math problems themselves. This is not on a conscious level, but the hypothesis is that this type of thought process takes away from one's ability to complete the task at hand, in this case math.<sup>6</sup>

Given how widespread stereotype threat appears to be it stands to reason that it likely affects women in surgery.<sup>5</sup> Women are still under-represented in medicine. As of 2014, only one-third of active physicians in the United States were women.<sup>12</sup> Gender bias affects women in medicine, and perhaps even more so in surgery.<sup>4,13-16</sup> These phenomena seem to lead to worse psychological well-being for women training to become surgeons. Despite exposure to such negative stereotypes in their science and medical coursework, women in surgical training still have chosen to pursue a male-dominated career path. It is not clear whether their performance in residency suffers under stereotype threat.

Here we examine the role of stereotype threat on surgical performance (as measured by a mental rotation test) and working memory among surgical residents. Previous research has demonstrated the validity of mental rotation ability as a proxy for surgical performance.<sup>17-19</sup> Our hypotheses are three-fold. First, we hypothesize that women will perform worse on the mental rotation task in the threat condition than in the no-threat condition due to the impact of stereotype threat. Second, we hypothesize that women will perform worse than men in the threat condition but not in the no-threat condition, where stereotype threat is absent. Third, we expect women's working memory to be reduced in the threat condition compared to the

no-threat condition, in line with research on the mechanism of stereotype threat and its impact.

## Materials and methods

### Data collection

In the context of a larger study, we performed a lab study to assess the impact of stereotype threat on mental rotation skills and working memory. We chose mental rotation skills as a test of surgical skill for several reasons: 1) mental rotation is an important skill for surgeons,<sup>18</sup> 2) this is a test for which a gender stereotype already exists, and 3) it is a test that is equally challenging for residents at all levels. In addition, mental rotation has previously been used as a proxy for surgical ability.<sup>17–19</sup> We followed this with a working memory test in order to assess the hypothesis that the mechanism by which stereotype threat decreases performance is via decreased working memory.<sup>11,20</sup> Additionally, working memory has been shown to be an important task for physicians since it impacts their ability to retain information gathered from patient interviews to make correct diagnoses.<sup>21</sup>

Participants were surgery residents at Stanford Health Care in the winter of 2011. Similar to classic stereotype threat experiments,<sup>7,10</sup> residents were randomized to either the threat or no-threat condition. Subsequently, they were administered a timed mental rotation test followed by a working memory test. Data presented here include residents who completed all tasks.

### Variables of interest

We collected data on participants' gender, age, ethnicity, marital status, post-graduate year, and surgical specialty. Ethnicity was modeled as a categorical variable with three levels: white, Asian/Pacific Islander, and other ethnicity.

As has been done previously, we administered the Vandenberg Mental Rotation Test (MRT) to assess mental rotation ability.<sup>22,23</sup> Residents were shown a target object and asked to choose which two of four images show the target object. There were four sets of six questions, for a total of 24 questions, and each set of six questions had a two-minute time limit. Figure 1 shows a sample question from the MRT. This task was administered in Qualtrics.

We assessed participants' working memory using the reading span task.<sup>24</sup> In the task, each resident was shown a series of items each containing three to seven sentences. Residents were asked to decide whether each sentence made sense and subsequently were shown a letter of the alphabet. At the end of the series, the participants were asked to recall the letters. Residents were administered a computerized version of the test in which the letter flashed on-screen after each sentence. Figure 2 shows a sample question from the reading span task. The task was run using Inquisit software.

### Conditions

Residents across all surgical specialties were randomized to either the threat or no-threat condition and read introductions for the tasks specific to their assigned group. In the threat

condition, residents were made aware that the study was measuring men's and women's performance, that research had shown men to outperform women, and that higher scores on the task were associated with increased surgical ability.<sup>25</sup> In the no-threat condition, the introduction stated that the study was investigating puzzle- and problem-solving skills, and that the questions were related to mental rotation and memory but were not correlated with mental ability. There was no mention of gender or surgical ability in the no-threat condition. Table 1 shows the precise wording for each condition. After the introduction, assessments of mental rotation and working memory were seamlessly administered electronically.

### Statistical analysis

We examined descriptive statistics for demographic characteristics, and the mean mental rotation and working memory scores were calculated by threat condition and gender. Differences in means by gender and by condition were assessed using *t*-tests. We then created two multivariable linear models to examine how gender and threat condition impacted mental rotation and working memory scores. Both models included ethnicity and the interaction between gender and threat condition. Age and post-graduate year were included as covariates initially but were ultimately removed from the models because they were not significant predictors of mental rotation or working memory and did not contribute to the predictive power of either model. All statistical analyses were performed using SAS (Version 9.4, SAS Institute, Cary, NC). The research protocol was approved by the Institutional Review Board (IRB) at Stanford University.

## Results

102 residents from multiple surgical specialties participated in this study (response rate 61%). Demographic information for the sample is presented in Table 2. The majority of the residents were male (60%), and the largest racial groups were whites (47%) and Asian/Pacific Islanders (32%). The sample included residents from five post-graduate years as well as some (11%) currently engaged in research or professional development time. The most common specialty was general surgery (38%).

### Mental Rotation

Our first hypothesis was that women would have better mental rotation performance in the no-threat condition than in the threat condition. We did not find evidence to support this hypothesis. Women's performance on the mental rotation test was similar in both conditions ( $p = 0.2629$ ).

Our second hypothesis was that women's mental rotation performance would be worse than the men's performance in the threat condition and that women's mental rotation performance would be the same as the men's performance in the no-threat condition. We did not find evidence to support this hypothesis. As shown in Table 3 and Figure 3, men's performance on mental rotation was significantly better, on average, than that of the women, regardless of condition ( $p = 0.0084$  in threat condition,  $p = 0.0063$  in no-threat). There were no significant differences in mental rotation scores between the threat and no-threat conditions within each gender ( $p = 0.2629$  among females,  $p = 0.1284$  among males).

We used a linear regression model to predict mental rotation score from gender, condition, the interaction between gender and condition, and ethnicity. Consistent with the initial *t*-tests, we found a statistically significant main effect for gender, with female residents having lower mental rotation scores on average compared to male residents regardless of condition ( $B = -3.61$ ,  $p = 0.0141$ ). There was no main effect of condition ( $B = 2.05$ ,  $p = 0.1024$ ). Thus, the threat condition did not negatively impact mental rotation performance for either men or women. The interaction of gender and condition was also not statistically significant ( $B = 0.05$ ,  $p = 0.9789$ ), indicating that the association between gender and mental rotation does not behave differently based on the condition. There was no significant difference in mental rotation score by ethnicity ( $p = 0.4436$ ).

### Working Memory

Our third hypothesis was that women's working memory would be depressed in the threat condition. We did not find evidence supporting this hypothesis. Women's working memory was similar in both the threat and no-threat conditions ( $p = 0.3991$ ). As shown in Figure 4, there was a statistically significant difference in working memory by gender; on average, women had higher working memory than men. As shown in Table 3, women also outperformed men within each condition ( $p = 0.0110$  for threat,  $p = 0.0032$  for no-threat).

In a similar regression model predicting working memory ability from gender, condition, the interaction term between gender and condition, and ethnicity, we found a statistically significant association between female gender and working memory ( $B = 13.80$ ,  $p = 0.0083$ ) such that women performed significantly better than men. The main effect of condition was not significant ( $B = 3.97$ ,  $p = 0.3676$ ). There was a statistically significant difference in working memory scores between residents of "other" ethnicity and whites ( $B = -9.57$ ,  $p = 0.0318$ ) such that whites performed better than non-white, non-Asian/Pacific Islander residents. There was no difference in performance between white and Asian/Pacific Islander residents ( $B = -7.01$ ,  $p = 0.0698$ ).

### Discussion

We aimed to examine the impact of stereotype threat on surgical performance and working memory in surgical residents. In agreement with previous research, women's performance on the mental rotation task was worse than men's performance regardless of threat condition.

Interestingly, women's working memory capacity was significantly higher than that of men. Finally, we found no evidence supporting the negative impact of stereotype threat on female surgical residents' performance on the mental rotation task or working memory. Women's performance on the MRT was the same regardless of whether or not the task was introduced as one in which men perform better, and working memory among women was similar across conditions.

As hypothesized, we found that men outperformed women on the MRT. Contrary to our hypothesis, this result was observed in both the threat and no-threat conditions. This is consistent with existing literature documenting superior scores for men on the MRT and

other visual-spatial processing tasks.<sup>26–28</sup> Studies have shown that visual-spatial tests correlate with surgical skills, so women's poorer scores on mental rotation tests would seem to indicate poorer surgical performance.<sup>18</sup> However, it has also been observed that among surgical residents women and men perform at an equally high level as measured by standardized clinical evaluations.<sup>29</sup> In addition, studies that have removed the time limit on the MRT have shown more comparable scores between men and women.<sup>30</sup> Thus, it has been proposed that the difference in mental rotation ability between genders is due in part to response speeds, which may be influenced by lack of confidence among women, rather than innate ability.<sup>30</sup> If the gender difference in mental rotation skills is due to time limits, then it is unclear whether the disparity is meaningful in the surgical setting where, with some exceptions, surgeons often have the opportunity to thoughtfully re-assess the operative plan as needed. It would be valuable to repeat our experiment without time limits on the MRT to examine if gender differences in mental rotation are abated.

Our findings indicated women outperform men in terms of working memory. While numerous studies have examined the gender gap in mental rotation abilities, there is little research on gender differences in working memory. One series of studies demonstrated an advantage in both verbal and spatial working memory in favor of women, yet at least one study found that men outperform women in working memory capacity.<sup>31,32</sup> Previous literature has not examined gender differences using the reading span test as a measure of working memory, as this study does. While women in this population demonstrated superior working memory, due to a weak research base it is unclear whether women in general have higher innate working memory capacity or if this group of women excelled in particular. Our finding that high-achieving women outperform men in terms of working memory seems natural considering they show remarkable, sustained achievement even in male-dominated environments. It may be true that women earning coveted residency spots have higher working memory than men earning the same spots. This would be consistent with data that show that women may have to be more qualified than men to reach the same level of achievement.<sup>16,33–35</sup>

Additionally, many studies have shown working memory to be associated with multitasking ability and highly correlated with reasoning ability, which are traits that have been traditionally associated with women.<sup>32,36,37</sup> For surgeons, and physicians in general, it is crucial to have excellent multitasking and reasoning skills. Managing multiple patients at once under time pressure, switching between tasks, and transferring of equipment and information have all been studied in relation to multi-tasking in a healthcare setting.<sup>38</sup> Because of the association between working memory and multitasking ability, it is possible that women surgeons and physicians have a natural advantage in these demanding situations. Perhaps all residents would benefit from training to improve multitasking and decision-making skills.

Interestingly and in contrast to our hypotheses, we found no effect of condition on either mental rotation or working memory. We hypothesized women's performance on the MRT would be worse in the threat condition. Additionally, as stereotype threat is hypothesized to harm performance due to interference with working memory, we expected women's scores on the reading span test to be lower in the threat condition compared to the no-threat

condition.<sup>11</sup> However, our findings indicated that among women there were no differences in mental rotation or working memory comparing the threat and no-threat conditions. One possible explanation for these findings is that this was due to our experiment failing to adequately establish stereotype threat. However, we believe this to be unlikely because our protocol for creating the threat and no-threat conditions was modeled after well-known experiments that have established stereotype threat.

Thus we propose that the lack of an effect of stereotype threat in our study is not due to a failing of the study design. Rather, it may be that the women in this sample are less susceptible to stereotype threat or could be exhibiting a challenge response. In a challenge response, performance is enhanced rather than threatened in response to a demanding task.<sup>39</sup> This response has been found in both perceptual-motor task performance<sup>40</sup> and cognitive task performance,<sup>10</sup> so it is reasonable to believe that a challenge response could affect performance on the mental rotation test or the reading span task. If it is true that these women are resistant to stereotype threat, this is a significant finding given the broadly demonstrated impact of stereotype threat on numerous populations. Women who are surgical residents have succeeded in many situations where a negative stereotype about their gender exists and have continued in a male-dominated career path. Therefore, it is possible that 1) they have adapted such that they are no longer affected by stereotype threat, 2) women who are able to reach this level of success in a male-dominated field may be intrinsically resilient to stereotype threat, or 3) a combination of both may occur. Whether the endurance shown among the women in this sample is reflective of an adaptation or self-selection – women who are more resilient to stereotype threat are the ones who succeed in male-dominated careers – or a combination of the two remains a subject for further study. It is also possible that the true potential of these women is hindered by stereotype threat to some degree even though performance outcomes do not differ between men and women. Given that women in male-dominated fields often have to work harder to achieve the same ends,<sup>16,33,34</sup> it is reasonable to believe in the absence of such threat, women might perform even better.

This work is limited by the fact that the data was collected at a single, selective medical center. We cannot say whether our findings would be replicated among a broader sample of surgery residents or among professionals. Certainly, further studies across multiple centers and perhaps across multiple professions would be needed to demonstrate whether this is a unique finding in this context. In addition, the mental rotation test is a surrogate for surgical skill rather than a direct measure of ability. Ideally, we could observe residents performing surgery or specific surgical skills to have a more high-fidelity measure. However, given the different types and levels of surgical residents we assessed, it is hard to select a skill that would be equally challenging and appropriate across all participants. Finally, we acknowledge that this is a lab study that allows hypotheses to be tested in controlled setting, and it may or may not directly reflect the circumstances under which stereotype threat is perceived in the working life of a surgeon. However, lab studies are useful as initial attempts to test phenomena, and we believe that this design is appropriate for quantifying stereotype threat and working memory given the current literature base.



## Conclusions

Our study indicated men outperformed women on the MRT, even in a sample of high-achieving surgical residents. However, women outperformed men on a working memory test regardless of whether they were in a condition designed to create stereotype threat. That we observed no effect of condition on either test suggests that this population of high-achieving women may be less susceptible to stereotype threat. The greater working memory of women is consistent with previous data suggesting that women have additional barriers to achieve success compared to men.

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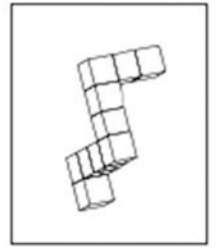
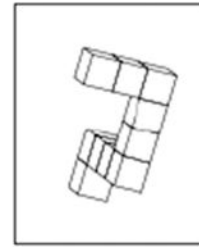
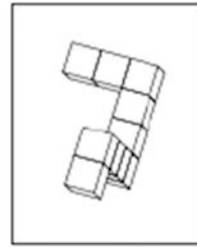
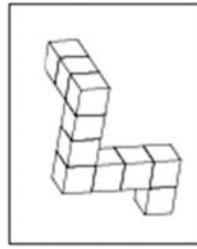
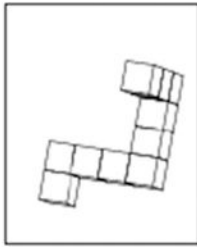
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**Research highlights**

- Residents were randomized to a stereotype threat condition or a no-threat condition.
- There was no condition effect on the residents' working memory or mental rotation.
- We found a gender difference in mental rotation such that men outperformed women.
- Women outperformed men on a working memory task regardless of condition.

Now look at  
this object:  
1.



Two of these four drawings show the same object.  
Can you find those two? Put a big X across them.

**Figure 1. Sample question from Mental Rotation Test**

In the Vandenberg Mental Rotation Test, the participant selects two of the four options on the right that are identical to the target figure shown on the left. ["used with permission from Michael Peters."]

## Reading Span

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(WMC)

The tiger leapt to the ridge. B

I'll never forget my days of combat. N

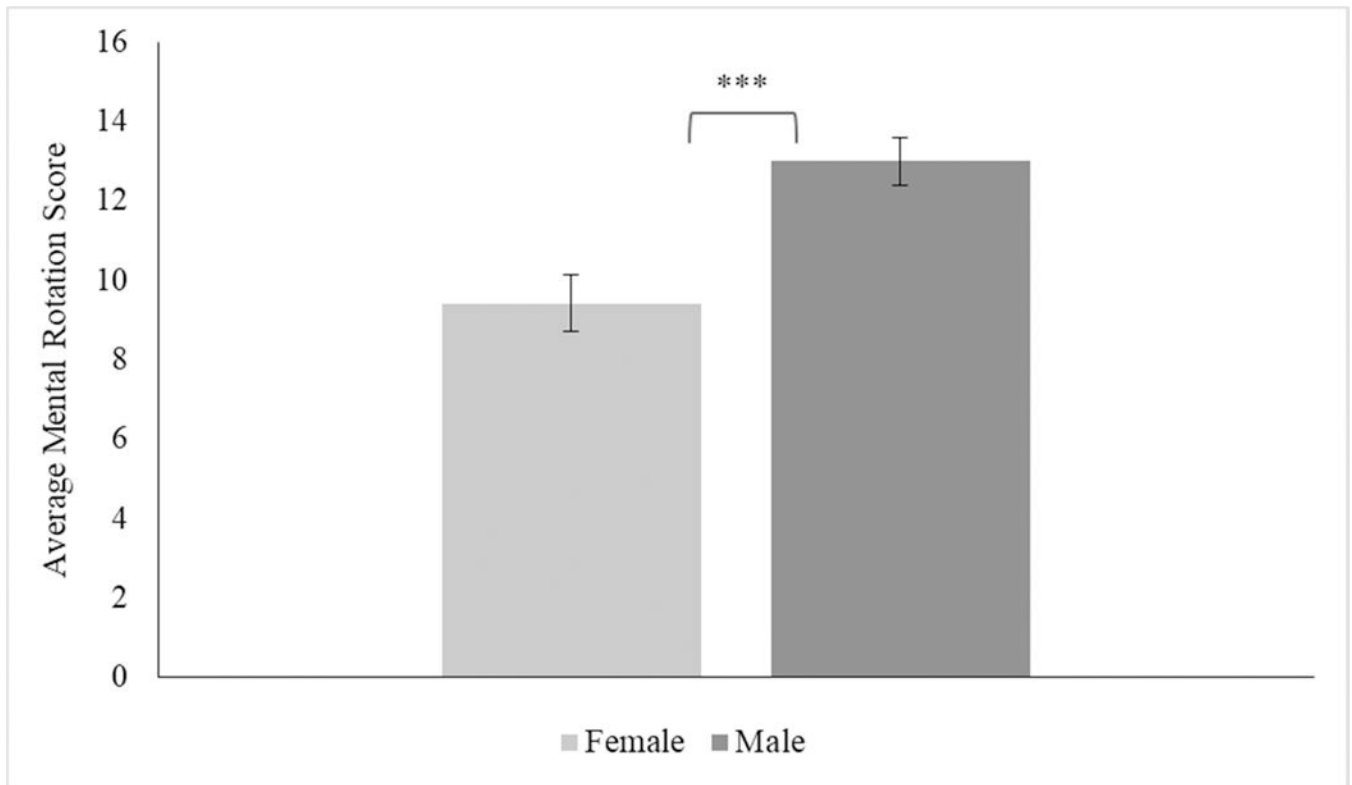
Andy was arrested for speeding. K

The mirror cast a strange reflection. J

Broccoli is a good source of nutrients. S

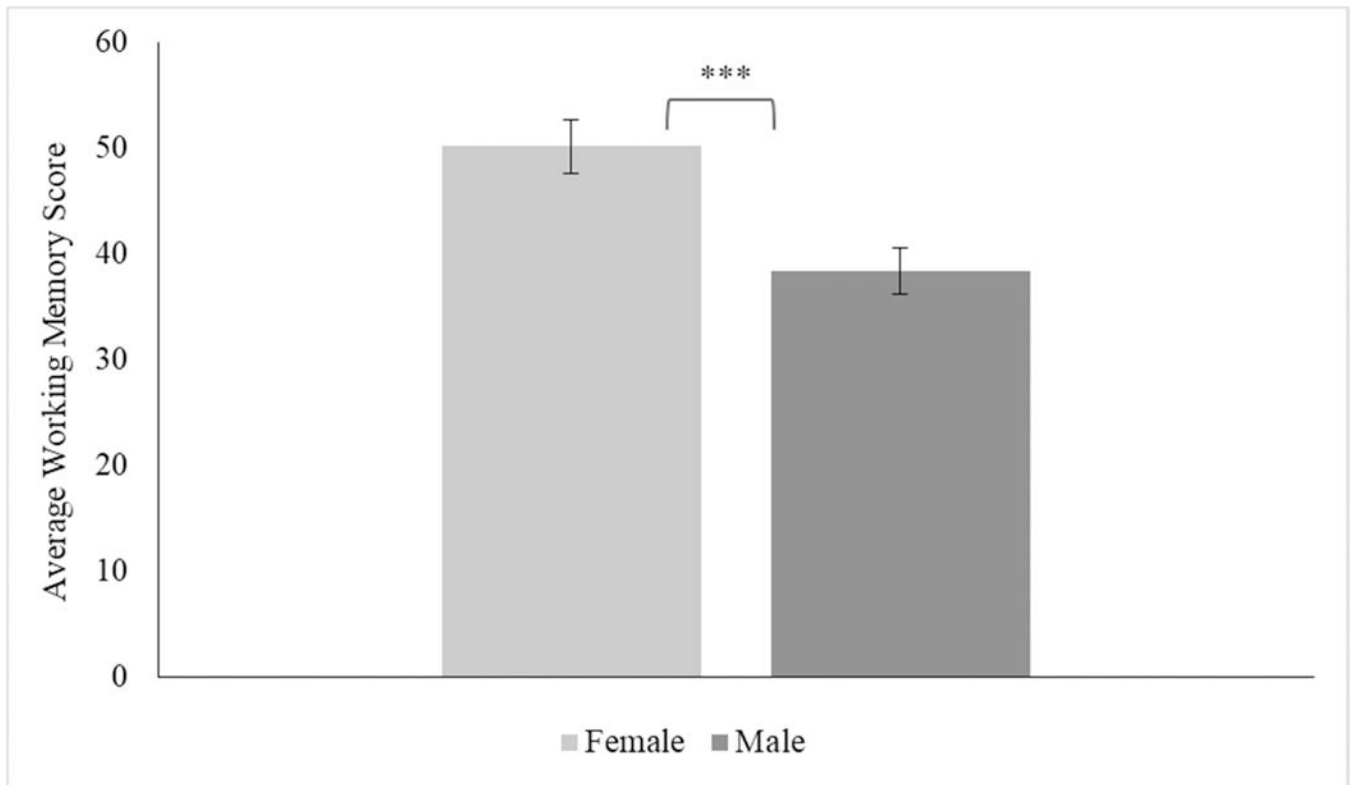
**Figure 2. Sample question from the reading span task**

In the reading span task, the participant is shown a series of items each containing three to seven sentences. He or she is asked to decide whether each sentence makes sense and subsequently is shown a letter of the alphabet. At the end of the series, the participant is asked to recall the letters.



**Figure 3. Mental rotation by gender**

The mean mental rotation score among female residents was 9.41 and among male residents was 13.0. The difference in working memory between genders was statistically significant ( $p = 0.0002$ ).



**Figure 4. Working memory by gender**

The mean working memory score among female residents was 50.10 and among male residents was 38.31. The difference in working memory between genders was statistically significant ( $p = 0.0008$ ).



**Table 1.**

Task introductions for threat and no-threat condition

Threat	No-threat
“We are interested in men and women’s performance on tests related to surgical ability. First, you will be completing a mental rotation test on which men have traditionally scored better than women. This test has also been found to correlate positively with surgical ability. Those who perform better on this test are better at performing complex surgical tasks. After the mental rotation test, you will be taking a memory test. These tests may be difficult for you. Because we want to get an accurate measure of your ability and limitations, it’s important that you give these tests your best effort.”	“We are interested in how people solve puzzles and problems. The following sets of puzzles and problems consist of new items we are pilot testing. They are related to mental rotation and memory. Although these tests are not indicative of mental ability, they help shed light on psychological processes involved in puzzle and problem solving. These tests may be difficult for you. In order to give us insight into problem solving processes it is important that you give these tests your best effort.”

**Table 2.**Demographics of residents (*N*= 102)

Characteristic	<i>n</i> (%)
Gender	
Female	41 (40.20%)
Male	61 (59.80%)
Post-graduate year	
1	28 (27.45%)
2	18 (17.65%)
3	14 (13.73%)
4	11 (10.78%)
5	20 (19.61%)
Research/professional development	11 (10.78%)
Specialty	
Cardiothoracic	5 (4.90%)
General surgery	39 (38.24%)
Neurosurgery	7 (6.86%)
Otolaryngology head and neck surgery	10 (9.80%)
Ophthalmology	4 (3.92%)
Orthopedics	14 (13.73%)
Plastics	10 (9.80%)
Urology	11 (10.78%)
Vascular	2 (1.97%)
Race/ethnicity ( <i>N</i> = 94)	
White	44 (46.81%)
Black or African-American	3 (3.19%)
Hispanic or Latino	8 (8.51%)
Asian/Pacific Islander	30 (31.91%)
Native American	0 (0.0%)
Middle Eastern	5 (5.32%)
Mixed Race	4 (4.26%)
Marital status ( <i>N</i> = 89)	
Single, never married	44 (49.44%)
Married	43 (48.31%)
Divorced	2 (2.25%)
Separated but married	0 (0.0%)
Widowed	0 (0.0%)

**Table 3.**

Mental rotation and working memory scores by condition and gender

Scale	Condition	N	Mean (SD)		p-value*
			Females	Males	
Mental rotation	Threat	55	10.13 (4.86)	13.88 (5.11)	0.0084
	No-threat	47	8.50 (4.15)	12.03 (4.09)	0.0063
Working memory	Threat	55	52.00 (15.14)	40.59 (16.30)	0.0110
	No-threat	47	47.67 (17.37)	35.79 (18.39)	0.0032

\*  
p-value comparing female and male residents within each threat condition