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Feeling Math Effects of Stereotype Threat, Evaluator Apprehension, and Social Identity on Heart Rate Variability and Female Math Performance

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Abstract

Women are vastly underrepresented in Science, Technology, Engineering, and Math (STEM) fields, and prevalent sex-stereotypes may be a contributing factor as to why, both academically and socially. This study investigated the relationships between stereotype threat, evaluator apprehension, and social math identity on female math performance and heart rate variability. Participants' received either a sex or a community prime and completed a written mathematical assessment and a verbal math task in the presence of an evaluator as heart rate variability was recorded. Evaluator sex was manipulated, and participants were surveyed and scored as having either "weak" or "strong" social math identities. Analysis by ANOVA failed to reproduce findings detailing depressed mathematical performance with regards to sex prime or heart rate variability, but Regression found both social math identity and evaluator sex to significantly predict heart rate variability (increased) at a time of stress during the experiment. These preliminary findings may help influence strategies for decreasing stereotype threat with regards to math performance in women.

Feeling Math Effects of Stereotype Threat, Evaluator Apprehension, and Social Identity on Heart Rate Variability and Female Math Performance

In modern academia and technology, a pressing issue exists in the disproportionate lack of women and minority students in science, technology, engineering, and math (STEM) fields (Khanna, 2013; Parmer, 2016). While educational institutions, private interest groups, corporations, and governments spend a significant amount of time, effort, and money on programs intended to even the playing field, the negative stereotypes and societal norms that hinder achievement of underrepresented groups cannot be so easily removed (United States, 2013; Lewin, 2012).

Stereotype threat is the feeling an individual has when they perceive risk of confirming a negative stereotype about their in-group as a self-characteristic; Stereotype threat encompasses the experience where one feels they will be judged by a relevant negative stereotype instead of by their merit (Steele, 1997; Spencer, Steele, & Quinn, 1999; Steele & Aronson, 1995). Stereotype threat has been shown to decrease cognitive performance when compared to neutral or positive prime control groups (Steele & Aronson 1995; Spencer, Steele, & Quinn, 1999).

Similarly, independent research has demonstrated that the behavior and performance of an individual can be affected by the presence of an audience or an evaluator. Evaluator apprehension then, is defined as the anxiety that stems from knowing one is being watched, evaluated, or judged (Rosenberg, 1965; Cottrell, Wack, Sekerak, & Rittle, 1968; Dickerson & Kemeny, 2004). In both instances, poor performance is due in large part to the depletion of cognitive resources such as working memory capacity (Schmader & Johns, 2003), and misdirected heightened psychological reactivity, such as increased heart rate (Steele & Aronson 1995; Schmader, Johns, & Forbes, 2008; Jamieson, Peters, Greenwood, & Altose, 2016). While not all increased physiological activity is deleterious, individuals who respond to cognitive tasks by appraising them as threats are more likely to exhibit decreased working memory capacity as compared to those who respond by appraising the task as a welcome challenge (Tomaka, Blascovich, Kibler, & Ernst, 1997; Schmader & Johns, 2003, Beilock, Rydell, & McConnell 2007). In the current study, we are interested in observing interactions between a physiological effect of stereotype threat, heart rate variability, and the mathematical performance of women in a high-achieving student population, and additionally, whether these physiological changes are

heightened with regards to the presence of an evaluator. Furthermore, we wish to examine whether manipulating the sex of the evaluator boosts or negates felt sex stereotype threat, and whether this potential effect can be observed physiologically.

A prominent sex stereotype is that females are predisposed to underperform in math when compared to males, despite the large body of research to the contrary. Meta-analysis of over 340 studies showed negligible differences in overall mathematical performance between sexes, even accounting for the slight variations observed across age groups (Hyde, Fennema, & Lamon, 1990; Lindberg, Hyde, & Peterson, 2011). Although no statistically significant differences exist between sexes regarding mathematical proficiency, research has shown that women perform poorly on mathematical assessments when primed with female identity (Brown & Josephs, 1999; Shih, Pittinsky, & Amdaby, 1999; Spencer, Steele, & Quinn, 1999; Ben-Zeev, Fein, & Inzlicht, 2005; Keller, 2002; Keifer & Sekaquaptewa, 2007). In one such study, undergraduate Asian-American women were asked to complete a quantitative mathematical assessment. Though all participants completed the same assessment, researchers observed depressed performance when participants' sex identity was made salient, and enhanced performance when their ethnic identity was made salient (Shih, Pittinsky, & Amdaby, 1999). Here, the positive stereotype is that Asian individuals outperform their peers in mathematics, while the negative stereotype is that women underperform in mathematics as compared to their peers. It stands to reason then that participants could be expected to perform better when primed with a positive stereotype.

This could also hold true for women of high achievement. For women admitted to technical institutions that value representation of women in STEM, female students are surrounded by capable female peers and professional role models as well as various social supports that aim to cultivate academic excellence and foster confidence in STEM (Beede, Julian, Langdon, McKittrick, Khan, & Doms, 2011). Given these support systems and the subsequent "break the stereotype" student culture that has emerged in their wake, it is possible that the math performance of high-achieving women of extremely selective technical institutions would be increased if they as participants were primed with the qualifier of their own position within their exclusive community, and depressed when primed with their sex identity. According to Steele (1997), to succeed in a given field of study, "one must be identified with school achievement in the sense of it being a part of one's self-definition" (p. 613). By calling attention to membership within an exclusive institution of STEM-focused higher education, this participant community

prime reinforces the idea of STEM identity and achievement; for this reason it is likely to act as a positive reinforcement, similar to how the sex prime initiates a potential stereotype threat response.

Both stereotype threat and evaluator apprehension decrease performance in large part due to heightened physiological reactivity and the subsequent depletion of cognitive resources necessary to perform the task at hand (Steele & Aronson 1995; Schmader et. al 2008; Jamieson et. al 2016). Research has shown that, on the cognitive side, stereotype threat makes stereotypic thoughts accessible (Davies, Spencer, Quinn, & Gerhardstein, 2002; Johns, Inzlicht, Schmader 2008). Moreover, as previously stated, research has shown stereotype threat and evaluator apprehension to reduce working memory capacity, hindering individual's abilities to perform well on cognitively intensive tasks (Inzlicht, McKay, & Aronson 2006; Johns, Inzlicht, & Schmader, 2008). Working memory is a limited cognitive resource, and is an articulated version of the central executive processor of short-term memory (Schmader & Johns, 2003). Working memory capacity includes both temporary storage of information as well as attention capability (Engle, Tuholsky, Laughlin, & Conway, 1999). When stereotype threat is activated, this attention capability is distracted, and prevents the whole of the individual's cognitive resources from being focused on the project at hand, resulting in depressed performance (Shmader & Johns, 2003; Beilock, Rydell, & McConnell 2007). In a lab setting, the anxiety produced by stereotype threat, or the anxiety produced by evaluator apprehension would be expected to consume cognitive resources that otherwise would be utilized for relevant math tasks, decreasing performance (Davies, Spencer, Quinn, & Gerhardstein, 2002).

The Current Study

The proposed study will further explore the linkages between stereotype threat, evaluation apprehension, and acute physiological stress, and their subsequent ramifications on female math performance. Though previous research has shown that female participants exhibit depressed performance when primed with a scenario-specific negative qualifier (here female identity), no studies have explored this phenomenon in conjunction with evaluator apprehension, especially within the context of a technical institution (STEM-oriented). The goal of the current research is to examine whether stereotype threat would decrease female math performance within the context of a technical institution, and further, to observe whether evaluator apprehension, and the

sex of the evaluator, when coupled with either a positive or a negative prime, influences the participants' mathematical performance and heart rate in a lab setting.

We hypothesized one, that female participants primed with their sex identity would exhibit depressed performance when compared to participants primed with their community identity at a selective STEM-oriented university, mirroring past studies. Two, we hypothesized interactions between stereotype threat prime, heart rate variability, and the sex of the evaluator, anticipating that by manipulating the sex of the evaluator, felt stereotype threat would either be amplified or decreased accordingly, with a male evaluator eliciting an increased felt stereotype threat an therefore heart rate variability; finally we hypothesized three, that the greater the participant's identity and affiliation with math, the less stereotype threat and depressed math score would be realized.

Method

Participants

Thirty four Participants were recruited from a medium sized private institution in New England via an online recruitment board. Due to the nature of the study, only female participants were recruited. Participants ranged from 18 to 26 years of age, with the median age being 21.

Design and Procedure

Prior to participating in the study, participants completed a general questionnaire regarding their health, basic demographics, and self-reported identity with their university. This pre-screening was completed upon registration within the recruitment software and was not associated with any particular study. Additionally, this pre-screening enabled the experimenter to ensure all participants were in overall good health and did not have any significant medical or psychological conditions that might interfere with the physiological measures (i.e. heart murmur, anxiety disorder).

After registering for the study and coming into the lab, the experimenter obtained informed consent from each participant. The experimenter then secured a POLAR heart rate monitor belt and watch. Electrodes present in the belt communicated wirelessly with the watch for the duration of cardiovascular data acquisition (CV). Participants were then asked to sit quietly for three minutes to obtain a resting CV baseline.

The experimenter explained the mathematical assessment and administered a cognitive appraisal form designed to gauge challenge or threat response to the impending task. The mathematical assessment was then administered to the participant via online survey and research platform Qualtrics. Participants were randomly assigned to indicate either their sex or their university affiliation prior to starting the assessment. The assessment lasted 24 minutes. Directly following the assessment, participants completed a second cognitive appraisal, designed to gauge participant response post-task.

Following completion of the assessment, the experimenter informed the participants that there would be a second, verbal math task. The experimenter then explained that another lab assistant would be evaluating the participant's accuracy, and then briefly introduced the evaluator. Participants were randomly assigned to be evaluated by either a male or a female lab assistant. Following the introduction, participants then completed the second pre-appraisal form, after which the evaluator immediately began the verbal math task. The evaluator instructed the participant to count backwards from a four-digit number by intervals of 13. In the event a mistake was made, the evaluator informed the participant to begin again from the original four-digit number. The mental arithmetic portion of the experiment lasted five minutes, during which the evaluator was instructed to maintain a neutral demeanor. Following completion of the verbal math task, the evaluator exited the room, and the participant completed the second post-appraisal form.

The experimenter then administered the Social Identities and Attitudes Scale, a Likert-Type scale questionnaire regarding felt stereotype threat and math and gender identity. The participant was then debriefed, and the POLAR heart rate apparatuses removed.

Materials

A number of surveys, tests, physiological measures, and questionnaires were utilized in this experiment. The initial Collective Self-Esteem questionnaire and the Social Identities and Attitudes Scale (SIAS) gauged affiliation with the university and identity with mathematics and gender.

Independent variables included the stereotype threat prime (female identity v. collegiate community identity) and the sex of the evaluator (male v. female). The dependent variables of

mathematical performance and heart rate were obtained by written assessment and through the use of the POLAR heart rate monitor belt.

Cardiovascular Parameters

Cardiovascular indices were obtained by way of a POLAR RS800 watch (POLAR USA, Inc.). POLAR heart rate monitors have been used extensively in psychophysiological studies and values are highly correlated with EKG acquisition devices (*r*s> 0.99. Heart rate, parasympathetic, and sympathetic indices (HR, HRV: 0.15-0.40. Hz, and VLF: 0.003-0.04 Hz respectively) can be reliably ascertained using the Polar RS800 heart rate monitor via the interbeat interval (IBI) values. The IBI series can then be extracted and analyzed with Kubios HRV Analysis software (BSAMIG, 2008). Data can then be manually corrected for artifact and scored offline.

A delta (change) score was formulated for each moment of interest (math assessment, metal arithmetic task) by subtracting the average heart rate from that of the recorded baseline. This ensured that all delta scores were relative, rendering individual differences in baseline irrelevant.

Mathematical Assessment

The mathematical assessment, administered through online survey and research platform Qualtrics, consisted of mathematical concepts for which proficiency is expected in most high school and college students. The 20-item assessment was adapted from Scholastic Aptitude Test (SAT) practice exams, and was timed and scored in accordance with SAT standards (SAT, 2016).

Verbal Mental Arithmetic

The verbal math task was adapted from one of the Trier Social Stress Task (TSST)'s three components, in which a participant is instructed to count backwards at specific intervals from an arbitrary four-digit number (Kirschbaum, Pirke & Hellhammer, 1993). The TSST is designed to acutely stress a participant through anticipation, public speaking, and mental arithmetic.

Social Identities and Attitudes Scale

The participants' affiliation with both math and gender, and potential perceived stereotype threat were measured by way of the Social Identities and Attitudes Scale (SIAS) (Picho & Brown, 2011). The questionnaire consisted of 42-items and was scored on a 7-point Likert scale ranging from 1 being "Strongly Disagree" to 7 being "Strongly Agree." Items included questions such as "Math is important to me," and "My gender influences how teachers interpret my behavior."

Results

Independent-samples t-test, Analyses of Variance (ANOVA) and hierarchical linear regressions were conducted to examine potential relationships between participant math score, stereotype threat condition, evaluator sex, heart rate variability, and strength of math and gender identity.

Does Stereotype Threat Influence Math Scores?

The researchers predicted increased math scores for participants who were primed with their community identity as opposed to their sex identity (stereotype threat condition). An independent-samples t-test was run to determine if there were differences in participant math score between stereotype threat conditions. Math scores were similar among participants who received the community prime (M = 0.63, SD = 0.12) and participants who received the sex prime (M = 0.61, SD = 0.17), M = -0.02, *95%* CI [-0.13, 0.08], $t(32) = -0.425$, $p = .673$.

Does Stereotype Threat and Evaluator Sex Influence Heart Rate Variability?

A one-way ANOVA was conducted to examine the effects of stereotype threat condition and evaluator sex on heart rate variability at the time of the back count (DeltaBackCount). The interaction effect between stereotype threat condition and evaluator sex was not statistically significant, F(1, 27), = 0.596, $p = .447$, partial $\eta^2 = .022$. Additionally, analysis demonstrated no statistically significant main effects of either stereotype threat or evaluator sex on heart rate variability at the time of the math assessment, F(1, 27), = 0.001, $p = .974$, partial $\eta^2 < 0.05$, and F(1, 27) = 2.296, $p = .141$, partial $\eta^2 = 0.078$ respectively.

Do Stereotype Threat, Evaluator Sex, or Social Math Identity Predict Heart Rate Variability?

A hierarchical multiple regression analysis was used to test if stereotype threat condition, evaluator sex, or participant social math identity significantly predicted heart rate variability (high) at the time of the back count (DeltaBackCount). Using the enter method, statistical difference was found in that stereotype threat condition, evaluator sex, and social math identity explain the variance of heart rate at the time of the back count ($F(3, 31) = 2.91$, $p = .0.52$, $R^2 = .49$, $R^2_{Adjusted} = .16$). The analysis showed that while the stereotype threat condition did not significantly predict heart rate variability ($\beta = -0.01$, $t(2.5) = -0.6$, $p = .952$), both evaluator sex (male) and social math identity (weak) were statistically significant with regards to predicting heart rate variability ($\beta = .37$, $t(2.6) = -2.6$, $p = .039$; $\beta = -.41$, $t(1.86) = -2.4$, $p = .024$ respectively). Even when controlling for baseline (heart rate), significant p-values changed negligibly ($p = .034$ and .024 respectively).

Discussion

Counter to prior research, no statistically significant difference was observed between stereotype threat condition groups with regards to mathematical performance. Though it is possible (and even likely) that this is attributable to limited sample size, it is also possible that the difference was negligible due to the strong math affinity observed in most participants in this sample. Participants were all enrolled in a STEM-oriented institution of higher education, and for this reason, may have been less susceptible to stereotype threat (Steele, 1997). A clear majority of participants reported strong social identities with regards to math, and for this reason, results were likely different from past research endeavors.

That heart rate variability at the time of the back count was not significantly influenced by stereotype threat condition or evaluator sex was surprising. Again, small sample size could have influenced this outcome, especially because the means were indicative of somewhat directional change in accordance with the prediction of the second hypothesis that a male evaluator would elicit increased stereotype threat and heart rate variability. The presence of a male evaluator, across both stereotype threat conditions, showed higher heart rate variability than did the presence of a female evaluator. Surprisingly though, for participants who received a female evaluator, heart rate variability was lower for participants who received the sex stereotype

threat prime rather than the community prime. Again, further research is necessary (and with a larger participant pool) to further expand on these trends.

Of most interest was the regression with regards to hypothesis three that the greater a female's social identity with math then the less likely they would experience stereotype threat and perform poorly on a math task. Though stereotype threat condition did not end up significantly affecting heart rate variability at the time of the back count, both evaluator sex (male) and social identity (weak) did. Those participants who had a male evaluator were more likely to experience increased heart rate variability, as were participants who scored on the weak end of social identity with regards to math. Upon further exploration however, no interaction was found between the variables (p = .364). Though no interaction was present, the data still suggests some concurrence with hypothesis three. It is likely then, that evaluator sex, and/or weak math identity could influence heart rate variability, and possibly, subsequent performance. In other words, while stereotype threat condition did not influence heart rate variability, evaluator sex did. It is possible that the presence of a male evaluator, regardless of the stereotype threat condition, invoked the same reaction in the female participants that the stereotype sex prime would: to depress math performance, and increase heart rate variability. This should be investigated further in future research.

Limitations and Further Research

The primary limitation of this study was the limited size of the participant pool. Ideally, each condition would have had 10-20 participants; however, the final participant pool did not exceed 40 participants. Further, due to random prime selection, evaluator availability, and the varying results of the Social Identities and Attitudes Scale, all conditions and variables were not equally represented with comparable sample sizes. With a larger sample size, statistical significance may have been observed with regards to math performance between stereotype threat conditions, among other items, or the trend of the means might have been more pronounced, allowing for a more nuanced look at the data.

Similarly, due to time constraints and participant pool size, the experiment was only able to focus solely on female students from a STEM-oriented institution while utilizing previous research and literature as a theoretical control group. While this experiment was well served for students within the intended STEM-oriented institution, future research should utilize

comparable student groups at neighboring institutions, with a more varied population. This would allow the experimenters to further examine effects with a non-STEM-oriented institution comparison group.

In addition, this experiment originally utilized pre and post appraisal forms with regards to the two math tasks. Given that the results of these items were not part of the in the initial research questions and predictions, they were ultimately excluded from analysis. Future research could look more into these items to investigate if mood across the experiment and between stereotype threat conditions influenced the results in any meaningful way. In a similar vein, as this was a preliminary investigation, we focused on heart rate variability to physiologically measure stress. Future research may want to assay participant saliva and investigate the stress hormone, cortisol as another medium for quantifying stress.

Lastly, regression analyses found evaluator sex to have a likely impact on predicting heart rate variability at a moment of high stress within the experiment. Though it was not an original research question, this also raises the question of whether the experimenter's sex influenced the results in any meaningful way. The primary investigator for this study was female. However, in an attempt to collect more participants, several participants were run by an available (and trained) male experimenter (but not enough to look at any statistical differences). Further research could explore whether or not the sex of the experimenter affected raw math performance or heart rate variability, and whether the presence of an experimenter at all (e.g., administering the study via paper or digital format to remove the experimenter) may influence results. .

Conclusion

Though hampered by small sample size, the experiment still produced enough information for thoughtful exploration. Previous findings regarding stereotype threat's negative impacts on female math performance could not be replicated here, though upon further investigation this may not be surprising. Given that the majority of participants in this study reported a strong social identity with regards to math, it is perhaps not surprising that they were not as "susceptible" to the threat of gender stereotypes on their math performance.

Additionally, the significance found regarding math identity and evaluator sex on increased heart rate variability was of interest. Though a vast amount of literature exists with

regards to stereotype threat for women and math, not as much research is dedicated to evaluator apprehension, especially when sex is introduced as a variable. If this study has shown anything it is that there is room for further exploration at this intersection. If a weak social math identity within females is likely to depress math performance, or if the presence of a male evaluator is likely to do the same, it would behoove psychologists and educators alike to be aware of the data. Only by further exploring these links can we better understand how to prevent depressed math performance outcomes, and promote increased math performance in women and other underrepresented groups. By promoting increased performance and stronger identity, maybe, just maybe, we'll also find more women (and other underrepresented groups) in STEM.

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