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Affective Factors Affect Visuospatial Decision-making: A Drift Diffusion Modeling Approach

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Abstract

Affective factors such as anxiety, confidence, and motivation can impair and enhance task performance. Here, we used drift diffusion modeling (DDM) to examine how these variables affect visualization, manipulation, and decision making on a mental rotation task (MRT). The effects of affective factors on visuospatial reasoning are largely unknown, perhaps in part because analyses are generally concerned with overall accuracy and reaction time (RT), without decomposing the stages of processing. With DDM, we decompose performance on a MRT into separate processing components, particularly the speed of information update (*drift rate*) and the amount of evidence accumulation (*decision threshold*). 106 adult participants performed a two-alternative forced-choice (2-AFC) MRT, and throughout, they rated their levels of anxiety, confidence, and motivation. We found that although anxiety, confidence, and motivation all impacted drift rate, only confidence affected the decision threshold. Moreover, we observed a unique role for confidence in mediating the links between gender and model parameters, as well as a unique moderating role of motivation in this mediation. Altogether, these findings shed light on the interrelations between affective factors in accounting for mental rotation performance in men and women, including the unique combination of confidence and motivation in explaining the gender difference in mental rotation performance.

Keywords: mental rotation; spatial cognition; decision-making; gender differences; drift diffusion modeling

Introduction

The effects of affective factors such as anxiety, confidence, and motivation on decision making are well documented (Hartley & Phelps, 2012; Lerner et al., 2015). However, little is known about how affective factors influence spatial tasks when effortful decisions are required. One such task is the mental rotation task (MRT), in which participants represent and rotate objects in one's mental space, deciding whether two objects are the same or different (Shepard & Meztler, 1971). This particular type of visuospatial decision making is associated with robust gender differences favoring males (Uttal et al., 2013; Voyer et al., 1995), but it is less clear why they exist and whether affective factors play a role in their instantiation. Research examining the potential role of affective factors in accounting for the gender-performance link provides evidence for mediating roles of spatial anxiety (Alvarez-Vargas et al., 2020; Sokolowski et al., 2019) and confidence (Estes & Felker, 2012) such that when anxiety or confidence is accounted for, gender differences in accuracy diminish. However, an open question remains: what role do affective factors play in influencing mental rotation performance in males and females? Despite the wealth of research on gender differences in spatial cognition, there are few mechanistic explanations for gender differences in terms of the link between affective factors and decision-stage processes.

One potential reason for this void is that it has proven difficult to isolate decision-stage processes from rotational processes on MRTs when using isolated analyses of accuracy and/or reaction time (RT). Previous studies have implemented signal detection theory to estimate the response criterion in the data analyses (Hirnstein et al., 2009). But this response criterion is more sensitive to parametrizing guessing behaviors than to parametrizing decision criterions. Furthermore, speed-accuracy trade-offs in behavioral responses are often inadequately addressed in experimental analyses that focus on accuracy and RT. Little is known about how affective factors influence mental rotation judgments under speed-accuracy trade-offs, as is typical in spatial tasks.

Drift diffusion modeling (DDM), which disentangles the separate stages of decision making, is well suited to dissociate the criteria settings from the quality of evidence accumulation (Ratcliff & Childers, 2015). On MRTs, DDM assumes that, after a stimulus is encoded, information from the stimulus (drift) accumulates with the noisy information (diffusion) until it reaches the decision threshold, at which point, a same/different choice is initiated (see Fig.1A). In this context, RT is the sum of the time needed for the information processing to reach the threshold plus the non-decision time (e.g., motor execution and perceptual encoding time). Thus, rotational processing can be dissociated

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from decision-stage processing while accounting for speed-accuracy trade-offs. The diffusion model has the following parameters: (1) drift rate (*v*), which represents the efficiency of information processing of mental rotation stimuli; (2) decision threshold boundary (*a*), which represents the amount of evidence needed to judge a same/different choice; and (3) non-decision time (*T*)[1], which represents perceptual encoding and motor execution.

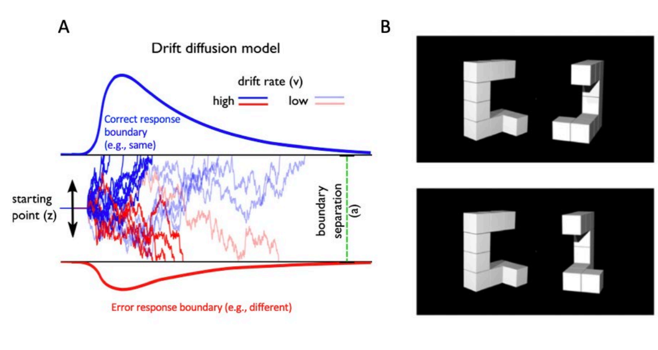
Here, through DDM, we investigate the link between affective factors and mental rotation decision-making in males and females. To our knowledge, no study has incorporated DDM in an investigation of affective factors in mental rotation in order to shed light on the gender difference in performance. A major strength of the current approach is that we are able to compare gender differences in both the rotational and decision-stage processes.

Anxiety. State anxiety, which is a transitory fear or apprehension towards a stimulus (Spielberger, 1983), can either enhance decisions by heightening perception of the stimulus or impair decisions by disengaging attention from the stimulus (Hartley & Phelps, 2012). Here, we hypothesized that anxiety would be associated with decreased information processing efficiency (i.e., drift rate). This hypothesis follows from attentional control theory (Coombes et al., 2009; Eysenck et al., 2007; Shackman et al., 2006), which suggests that higher anxiety drains working memory resources needed for tasks such as mental rotation. Moreover, such rumination may be particularly damaging to an analytical strategy (i.e., comparing parts or features of objects), which may be overrepresented in females (Geiser et al., 2006). We also hypothesized that higher state anxiety might be associated with a lower decision threshold because anxious individuals are more likely to engage in an avoidance strategy which could involve disengagement from evidence accumulation. Related research on math anxiety suggests such a possibility insofar as math anxious individuals engage in avoidance behaviors by decreasing effort on math problems (Choe et al., 2019).

Confidence. Confidence is defined as the degree to which one believes that one's judgment is correct. Studies have found that confidence is positively correlated with mental rotation accuracy in both male and female participants, but males report relatively higher confidence (Cooke-Simpson & Voyer, 2007; Estes & Felker, 2012). There is also evidence that when participants are allowed to update their initial answer on a mental rotation task, females (who report relatively lower confidence) revise their answers more than males (Cross et al., 2017). Given these findings, we hypothesized that confidence would be positively associated with drift rate by enhancing processing efficiency and negatively correlated with decision threshold by decreasing the amount of evidence accumulation.

Motivation. Motivation is defined as the willingness to achieve a task goal. Whereas anxiety captures fear and nervousness in spatial experiences, motivation captures how one approaches spatially-related activities and the amount of effort one exerts on a task. Previous research has shown that mental rotation performance improves when conditions elevate motivation, such as self-affirmation (Martens et al., 2006), compensating stereotypes (Wraga et al., 2006), and believing that effort and practice matter, particularly in female participants (Moè & Pazzaglia, 2010). However, it remains unclear how motivation affects drift rate and/or decision threshold across genders. We hypothesized that motivation might be positively correlated with drift rate by enhancing information processing efficiency and positively correlated with decision threshold by increasing the amount of evidence accumulation.

Each of the aforementioned affective factors may operate independently on performance or by way of interactions with each other. To this end, we examined the mediating roles of affective factors in accounting for gender-performance links. We were particularly interested in the gender-specific effects of affective factors on decision-making because, as previously noted, females tend to report higher levels of spatial anxiety and lower levels of confidence compared to males.



[1] Nondecision time (*T*) and a priori bias (*z*) are not considered further in the present paper. *T* is composed of encoding + motor execution. Although some researchers have suggested that males and females differ in their encoding of the stimuli, encoding and motor execution are not dissociable in this analysis. Thus, we do not report analyses of *T*. *z* is assumed to be 0.5 (i.e., equal bias for either choice) for both genders; thus, *z* is not reported.

Fig.1. (A) Schematic illustration of the drift diffusion model. Information accumulates until a boundary is reached. Adapted from HDDM (Wiecki et al., 2013) in the context of a same trial. (B) Examples of same (top) and different (bottom) trials on the MRT (Ganis & Kievit, 2015).

Method

Participants

106 adults were recruited through the *Prolific* online testing platform (50% males; age range:18 – 40 years). All participants were right-handed and reported normal or corrected-to-normal vision. All participants reported that their gender identity matched their birth sex. Written informed consent was provided prior to participation. A sample size of 100 was determined by a priori power analysis. Experimental procedures were approved by the Emory University Institutional Review Board (IRB).

Procedure

Mental Rotation Task (MRT). Participants completed a chronometric 2AFC MRT (Fig. 1B), in which participants judged whether pairs of objects were identical or different. Objects were selected from a stimulus library with enhanced perspective, depth, and shading cues compared to the original stimuli of Shepard and Metzler (1971) (Ganis & Kievit, 2015). Object pairs are considered identical if one object can be rotated into congruence with the other ('same' trials) and different if they cannot be rotated into congruence ('different/mirror' trials). Across a total of 96 trials, object pairs differed by one of four orientations: 0°, 50°, 100°, and 150° (counterbalanced order), with an equal number of same and different trials.

Participants were instructed to "respond as quickly and as accurately as possible" within 7500 ms, and they received a prompt to respond without the stimulus after the elapsed time. Trials were separated by an interval of 200 ms.

State Affective Factors. In 24 randomly-selected trials (balanced across angular disparity and blocks), participants rated their levels of anxiety, confidence, and motivation for the preceding trial using a 7-point Likert scale (i.e., "How anxious/confident/motivated were you on the previous trial?"; 1 = *not at all,* 7 = *extremely*). Presentation order for each rating type (anxiety, confidence, or motivation) was counterbalanced across trials.

Trait Anxiety. At the end of the MRT, general (trait) anxiety was assessed by the trait subscale (STAI-T) of the State-Trait Anxiety Inventory (Spielberger et al., 1983). Participants rated their level of anxiety on 20 statements (e.g., "I feel like a failure"; 5-point scale). Trait anxiety was used as a contrast to state affective factors in order to test for the specificity of effects.

Hierarchical Drift Diffusion Modeling (HDDM)

Task performance was modeled by fitting HDDM (Wiecki et al., 2013) to participant accuracy and RT data. This approach accounts for individual differences in parameter estimates. All models were fit to individual participants' data using hierarchical Bayesian analyses.

Pre-processing of RT data. Of the 106 participants, six were excluded due to technical problems or a failure to pass attention checks. The final sample consisted of 100 participants (50% males). Data were trimmed by removing RTs faster than 300 ms and slower than 7500 ms (1.2% of total trials); RTs were also trimmed per participant (2.5 SD). Both correct and error trials were included in the analyses. Trial-by-trial RT and accuracy data for each participant were inputted into HDDM.

Model specifications. Parameter estimates consisted of drift rate (v) and decision threshold (a). Group mean posteriors of the hierarchical model were used to perform statistical analyses. All models excluded 5% of outlier trials and used weakly informative priors by default (Wiecki et al., 2013).

Models were fitted to same and different trials separately because these two types of trials may be processed differently and diverge early in processing (Toth & Campbell, 2019). For simplicity, only the same trials are analyzed in the current paper. Analyses of different trials can be found in supplemental material (OSF link).

Model fits. HDDM was checked for model convergence by inspecting traces of model parameters and the Gelman-Rubin convergence diagnostic statistics (Gelman & Rubin, 1992). Model parameters were analyzed using Bayesian hypothesis testing (95% Credible Intervals).

Results

In preliminary analyses, we confirmed that both accuracy and RTs varied as a function of the angular disparity between objects. As angular disparity increased, participants' accuracy decreased (β = -.18, p < .001) and RTs increased (β = .81, p < .001), consistent with the angular disparity effect.

Gender Differences in Model Parameters and Affective Ratings

Model Parameters. Analyses of drift rate and decision threshold also revealed effects of angular disparity. DDM fits for drift rate decreased monotonically with angular disparity (Fig. 2A; posterior probability >

95%), whereas decision threshold, increased with angular disparity (Fig. 2B, posterior probability > 95%), as expected if trials with larger angular differences between objects are relatively more difficult. These results demonstrate that model fits captured the patterns observed in behavior (with accuracy and RT), providing support for DDM as a valid index of performance.

Subsequent analyses tested for effects of participant gender. DDM fits for drift rate revealed lower drift rates for females compared to males (Fig. 2C, 97.1% posterior probability), suggesting slower information uptake in female participants compared to male participants. In the case of decision threshold, the gender difference approached significance (Fig. 2D; 92.7% posterior probability), with female participants displaying a relatively smaller decision threshold compared to male participants, which may indicate an avoidance strategy in decision making as reflected by less evidence accumulation.

Affective Ratings. Mean ratings were obtained across the rating trials. A MANOVA, with gender as a fixed factor, was conducted; the dependent variables were state affective ratings (anxiety, confidence, motivation), and trait anxiety (Table 1). There were significant gender differences in state anxiety and confidence, with females reporting higher anxiety and lower confidence than males. No other significant gender differences were found, though state motivation approached significance (such that females were relatively more motivated on the task).

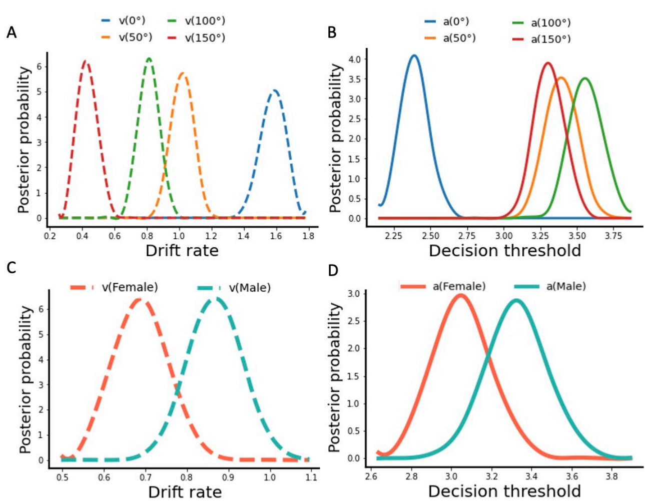


Fig. 2: DDM fits for angular disparity (A & B) and gender (C & D).

Table: 1: Means, *SD*s, *F* Values, *p* Values, and Effect Sizes for Comparisons of Gender Differences

Predictor	Female		Male				
	Mean	*SD*	Mean	*SD*	*F*	*p*	η_p^2
State anxiety	2.98	1.53	2.41	1.15	4.32	.040*	.04
State confidence	4.65	1.25	5.27	1.17	6.48	.012*	.06
State motivation	5.63	1.27	5.14	1.54	3.04	.085	.03
Trait anxiety	50.10	11.92	46.76	10.02	2.30	.132	.02

Note: * $p < .05$

Relations Between Affective Ratings and Model Parameters

We next performed separate regression analyses to test for relations between each of the affective ratings and model parameters, controlling for trait anxiety. Affective ratings and trait anxiety were standardized.

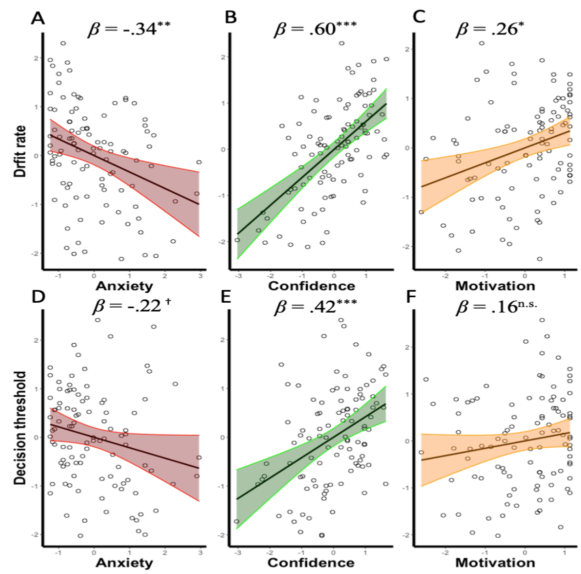


Fig. 3: Partial regression plots of the relations between each of the affective ratings and each model parameter (drift rate and decision threshold), controlling for trait anxiety. Betas are standardized coefficients. $^{\dagger}p = .05 - .10$, $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$.

Anxiety[2]. Higher state anxiety was associated with lower drift rates (Fig. 3A; $\beta = -.34$, $p = .002$, 95% CI [-.55, -.12]), and there was a marginal association with decision thresholds (Fig. 3D; $\beta = -.22$, $p = .055$, 95% CI [-.44, .01]). These findings suggest that state anxiety may disrupt processing efficiency. Its effect on evidence accumulation, however, is less clear. Although not statistically significant, the negative coefficient indicates that participants may have decreased evidence accumulation as anxiety increased.

[2] Analyses of the relation between trait spatial anxiety (SAQ; Lyons et al., 2018) and model parameters found similar results.

Confidence. Higher confidence was associated with both faster drift rates (Fig. 3B; $\beta = .60$, $p < .001$, 95% CI [.44, .77]) and higher decision thresholds (Fig. 3E; $\beta = .42$, $p < .001$, 95% CI [.23, .61]). These findings suggest that confidence affects both processing efficiency and evidence accumulation, such that, when confidence is higher, processing efficiency is better and participants engage in more evidence accumulation.

Motivation. Higher motivation was associated with faster drift rates (Fig. 3C; $\beta = .60$, $p = .011$, 95% CI [.06, .45]), but there was no association with decision thresholds (Fig. 3F; $\beta = .16$, $p = .120$, 95% CI [-.04, .36]), suggesting that motivation enhances processing efficiency but may not affect evidence accumulation.

Do Affective Factors Account for the Gender Differences in Model Parameters?

Given the aforementioned effects of gender and affective factors on model parameters, we next tested for mediation by affective factors (anxiety, confidence, and motivation) between gender and model parameters in separate analyses. Gender was dummy coded (female = 0, male = 1) so that positive coefficients indicated higher scores for male participants. All variables were standardized. Effects were assessed by bias-corrected bootstrapped 95% CIs from 2000 resamples. Gender positively predicted anxiety ($\beta = .47$, 95% CI [.08, .85]), but negatively predicted confidence ($\beta = .50$, 95% CI [.11, .88]). Gender was not significantly correlated with motivation ($\beta = -.35$, 95% CI [-.74, .05]). Tests of mediation for anxiety, confidence, and motivation are presented next.

Drift Rate. As shown in Figure 4A, analyses revealed that with the inclusion of confidence, the direct effect between gender and drift rate became non-significant, suggesting that confidence mediated the path between gender and drift rate. By contrast, there was no evidence of mediation by anxiety or motivation. Importantly, we included gender as a mediator to test for model misspecification; gender was not significant. Altogether, these results provide evidence for a unique effect of confidence in accounting for the gender difference in processing efficiency on the MRT.

We next tested for whether anxiety or motivation moderated the mediation effect of confidence. We specified that anxiety or motivation moderated both the indirect and direct paths in the mediation models. Results revealed that motivation, but not anxiety, moderated the path from gender to drift rate (Fig. 4C). Simple mediated effects showed that confidence partially mediated the relation between gender and drift rate in participants with low motivation, as path *c'* was lower than path *c*, but still significant. By contrast, participants with high motivation did not show gender differences in drift rates (non-significant *c* and *c'* paths). These results suggest that the mediating role of confidence in the gender-drift rate link may be specific to participants who are low in motivation.

Decision Threshold. Although gender only marginally predicted decision threshold (92.7% posterior probability), we nevertheless tested for the mediating roles of all affective factors, given extant findings and a priori predictions. As Figure 4B illustrates, analyses revealed that with the inclusion of confidence, the direct effect between gender and decision threshold was non-significant, suggesting a mediating role of confidence along this path. By contrast, there was, again, no evidence of mediation by state anxiety or state motivation. Importantly, we also included gender as a mediator to test for model misspecification; gender was not significant. These findings suggest a unique role for confidence among the affective factors in accounting for the gender difference in evidence accumulation on the MRT.

We then tested for whether anxiety or motivation moderated the mediating effect of gender to decision threshold through confidence. Results showed that motivation, but not anxiety, moderated the path from gender to decision threshold (Fig. 4D). Simple mediated analyses showed that confidence partially mediated the relation between gender and decision threshold in participants with low motivation, as path *c'* was lower than path *c*, but still significant. By contrast, participants with high motivation did not show gender differences in decision thresholds (non-significant *c* and *c'* paths). These results suggest that the mediating role of confidence in the gender-decision thresholds link may be specific to participants with low motivation.

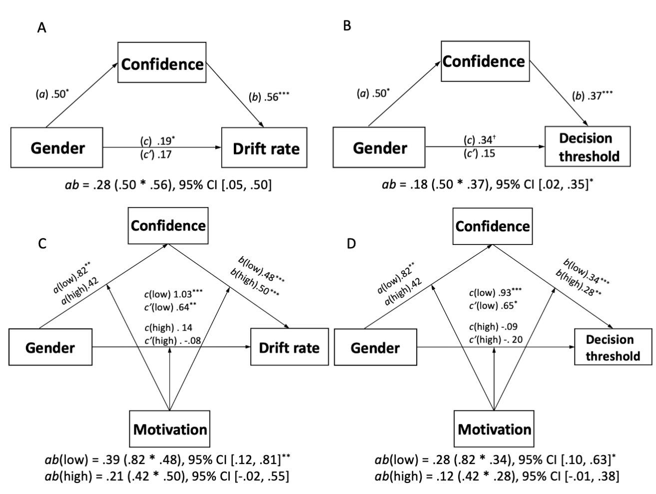


Fig. 4: Path diagrams showing standardized coefficients for mediation models of drift rate (A) and decision threshold (B), as well as conditional indirect effects of gender and drift rate (C) and gender and decision threshold (D) via confidence, at low (-1 SD) and high (+1 SD) motivation. The *c* paths represent the total effects. The *c'* paths represent the direct effects. The *ab* paths represent the indirect effects. Only significant (or marginal) effects are noted: $^{\dagger}p$ = .05 - .10, $^{*}p$ < .05, $^{**}p$ < .01, $^{***}p$ < .001.

Discussion

The present study provides a novel exploration of performance-related factors on a visuospatial task, for which gender differences have been robustly reported. Using DDM, we shed new light on the potential roles of affective factors in the gender-performance link on a MRT.

We found that anxiety was negatively associated with drift rate, whereas confidence and motivation were positively associated with drift rate. In other words, although higher anxiety reduces processing efficiency, higher confidence and higher motivation enhance it. We also found that only confidence predicted decision threshold, such that participants accumulated more evidence when more confident. Taken together, these findings highlight important relations between affective factors and decision making such that anxiety, confidence, and motivation may all affect processing efficiency. Confidence, however, was the only affective factor to mediate the links between gender and both processing efficiency and evidence accumulation.

Anxiety. Consistent with our hypothesis, our results establish a robust link between anxiety and processing efficiency, in line with attentional control theory (Eysenck et al., 2007; Ramirez et al., 2012). We also found some preliminary evidence supporting the role of anxiety in decision threshold, which may suggest that high levels of anxiety induce avoidance, with less evidence accumulation during the task. This appears consistent with studies showing that participants react faster after a fearful stimulus than after a neutral stimulus on MRTs (Borst et al., 2012). However, it is an open question whether anxiety may interact with other affective factors to increase the decision threshold rather than decrease it.

Confidence. Our results showed that confidence is positively associated with processing efficiency and evidence accumulation. Based on this, confidence may offset anxiety to increase processing efficiency and evidence accumulation. Previous work in line with such a possibility found reductions of drift rate after errors (Notebaert et al., 2009; Purcell and Kiani, 2016), such that error processing may have diverted attention from the task at hand (Desender et al., 2019). Relatedly, participants may engage less with the task after perceived errors, eliciting avoidance, perhaps similar to the effects of anxiety on decision thresholds. This suggests a potential role for metacognitive monitoring of the difficulty and accuracy of responses.

Motivation. Our results highlight that motivation may enhance both processing efficiency and evidence accumulation. In post hoc analyses, we found that whereas motivation is positively associated with drift rates and decision thresholds in female participants, such relationships were not observed in male participants. Previous work has suggested that teaching motivation is particularly effective for females in MRTs (Moè, 2016), and our results are in line with such a possibility.

Confidence and Motivation. A novel finding of the current work is that confidence mediates the gender differences in drift rate and decision threshold in individuals with low motivation. It is possible that confidence, resulting from perceived correctness, may boost approach behaviors in females with low motivation who have adopted an avoidance motivation strategy, resulting in increases in processing efficiency and evidence accumulation comparable to that of males. However, females and males with high motivation may have had an approach motivation strategy that works optimally on the task regardless of how they perceived the accuracy of their answers. This possibility highlights the importance of motivation in affecting gender differences on MRTs. However, given that the mediation (vis-à-vis confidence) was only partial, future work will be needed to decipher the role of other potential mediators.

In sum, our findings motivate theoretical questions about how affective factors influence decision making on MRTs. We suspect that our results will have implications for reducing gender differences in spatial tasks by targeting affective interventions, such as boosting confidence and motivation.

References

Alvarez-Vargas, D., Abad, C., & Pruden, S. M. (2020). Spatial anxiety mediates the sex difference in adult mental rotation test performance. Cogn Res Princ Implic, 5(1), 31.

Choe, K. W., Jenifer, J. B., Rozek, C. S., Berman, M. G., & Beilock, S. L. (2019). Calculated avoidance: Math anxiety predicts math avoidance in effort-based decision-making. Sci Adv, 5(11), eaay1062.

Cooke-Simpson, A., & Voyer, D. (2007). Confidence and gender differences on the Mental Rotations Test. Learning and Individual Differences, 17(2), 181-186.

Coombes, S. A., Higgins, T., Gamble, K. M., Cauraugh, J. H., & Janelle, C. M. (2009). Attentional control theory: anxiety, emotion, and motor planning. J Anxiety Disord, 23(8), 1072-1079.

Cross, C. P., Brown, G. R., Morgan, T. J. H., & Laland, K. N. (2017). Sex differences in confidence influence patterns of conformity. Br J Psychol, 108(4), 655-667.

de Visser, L., van der Knaap, L. J., van de Loo, A. J., van der Weerd, C. M., Ohl, F., & van den Bos, R. (2010). Trait anxiety affects decision-making differently in healthy men and women: towards gender-specific endophenotypes of anxiety. Neuropsychologia, 48(6), 1598-1606.

Desender, K., Boldt, A., Verguts, T., & Donner, T. H. (2019). Confidence predicts speed-accuracy tradeoff for subsequent decisions. Elife, 8, e43499.

Estes, Z., & Felker, S. (2012). Confidence Mediates the Sex Difference in Mental Rotation Performance. Archives of Sexual Behavior, 41(3), 557-570.

Eysenck, M. W., Derakshan, N., Santos, R., & Calvo, M. G. (2007). Anxiety and cognitive performance: Attentional control theory. Emotion, 7(2), 336-353.

Ganis, G., & Kievit, R. A. (2014). A New Set of Three-Dimensional Shapes for Investigating Mental Rotation Processes: Validation Data and Stimulus Set. Journal of Open Psychology Data, 3(1), e3.

Geiser, C., Lehmann, W., & Eid, M. (2006). Separating “Rotators” From “Nonrotators” in the Mental Rotations Test: A Multigroup Latent Class Analysis. Multivariate Behav Res, 41(3), 261-293.

Hartley, C. A., & Phelps, E. A. (2012). Anxiety and decision-making. Biol Psychiatry, 72(2), 113-118.

Hirnstein, M., Bayer, U., & Hausmann, M. (2009). Sex-specific response strategies in mental rotation. Learning and Individual Differences, 19(2), 225-228.

Lawton, C. A. (1994). Gender differences in way-finding strategies: Relationship to spatial ability and spatial anxiety. Sex roles, 30(11), 765-779.

Lerner, J. S., Li, Y., Valdesolo, P., & Kassam, K. S. (2015). Emotion and decision making. Annu Rev Psychol, 66, 799-823.

Martens, A., Johns, M., Greenberg, J., & Schimel, J. (2006). Combating stereotype threat: The effect of self-affirmation on women’s intellectual performance. Journal of Experimental Social Psychology, 42(2), 236-243.

Moè, A., & Pazzaglia, F. (2010). Beyond genetics in Mental Rotation Test performance. Learning and Individual Differences, 20(5), 464-468.

Moè, A. (2016). Teaching motivation and strategies to improve mental rotation abilities. Intelligence, 59, 16-23.

Ramirez, G., Gunderson, E. A., Levine, S. C., & Beilock, S. L. (2012). Spatial anxiety relates to spatial abilities as a function of working memory in children. Q J Exp Psychol (Hove), 65(3), 474-487.

Ratcliff, R., & Childers, R. (2015). Individual Differences and Fitting Methods for the Two-Choice Diffusion Model of Decision Making. Decision, 2(4), 237-279.

Searle, J. A., & Hamm, J. P. (2017). Mental rotation: an examination of assumptions. Wiley Interdisciplinary Reviews: Cognitive Science, 8(6), e1443.

Shackman, A. J., Sarinopoulos, I., Maxwell, J. S., Pizzagalli, D. A., Lavric, A., & Davidson, R. J. (2006). Anxiety selectively disrupts visuospatial working memory. Emotion, 6(1), 40-61.

Shepard, R. N., & Metzler, J. (1971). Mental rotation of three-dimensional objects. Science, 171(3972), 701-703.

Sokolowski, H. M., Hawes, Z., & Lyons, I. M. (2019). What explains sex differences in math anxiety? A closer look at the role of spatial processing. Cognition, 182, 193-212.

Spielberger, C. D. (1983). State-trait anxiety inventory for adults.

Thoresen, J. C., Francelet, R., Coltekin, A., Richter, K.-F., Fabrikant, S. I., & Sandi, C. (2016). Not all anxious individuals get lost: Trait anxiety and mental rotation ability interact to explain performance in map-based route learning in men. Neurobiology of learning and memory, 132, 1-8.

Uttal, D. H., Meadow, N. G., Tipton, E., Hand, L. L., Alden, A. R., Warren, C., & Newcombe, N. S. (2013). The malleability of spatial skills: a meta-analysis of training studies. Psychol Bull, 139(2), 352-402.

Voyer, D., Voyer, S., & Bryden, M. P. (1995). Magnitude of Sex Differences in Spatial Abilities: A Meta-Analysis and Consideration of Critical Variables. Psychological Bulletin, 117(2), 250-270.

Wiecki, T. V., Sofer, I., & Frank, M. J. (2013). HDDM: Hierarchical Bayesian estimation of the Drift-Diffusion Model in Python. Frontiers in Neuroinformatics, 7, 14.

Wraga, M., Duncan, L., Jacobs, E. C., Helt, M., & Church, J. (2006). Stereotype susceptibility narrows the gender gap in imagined self-rotation performance. Psychonomic Bulletin & Review, 13(5), 813-819.