



Sex Differences during Visual Tracking and Emotion Recognition

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Authors' contributions

This work was carried out in collaboration between all authors. Authors JAP and RMG designed the study, wrote the protocol and supervised the work. Authors RG and VWC carried out all laboratories work and performed the statistical analysis. Authors RG and VWC managed the analyses of the study. Authors RG and VWC wrote the first draft of the manuscript. Authors RG and JAP managed the literature searches and edited the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To test cognitive sex differences in a visual tracking task. We hypothesize that males show a bias for bottom-up strategy during the tracking task, while females use more of a top down strategy during tracking.

Study Design: Cognitive sex differences typically favor males in visual tracking tasks while females exhibit an advantage in object recognition tasks, including recognition of emotional expressions. Many studies have attributed these advantages to strategies and biases for deploying bottom-up information processing by males and top-down processing by females. These biases have implications for the concept of dorsal and ventral visual streams and their roles in spatial representation and embodied cognition.

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Methodology: We used a computer task that measures accuracy and reaction times in visual tracking and emotion recognition tasks using slow and fast trials. Three different types of trials were presented: visual tracking only, emotion recognition only, and combined visual tracking and emotion recognition, in which trials were randomly presented.

Results: In the visual tracking task males performed with greater accuracy, although not necessarily faster than females. In the emotion recognition task, males and females performed with equal accuracy, but females improved their performance in the combined task, whereas males did not. Reaction times showed that all participants reacted faster and more accurately in the fast compared to slow speed trials, suggesting a role for embodied representation of stimulus speed.

Conclusion: The overall pattern of results is consistent with and extends previous work implying that sex-related biases in low-level visual processing play an important role in the expression of cognitive sex differences.

Keywords: Bottom-up; top-down; dorsal stream; ventral stream; embodied cognition.

1. INTRODUCTION

The presence of cognitive sex differences in humans is well-established, and is associated with changes in neural circuitry supporting those differences [1-6]. In general, males tend to display an advantage in tasks that involve actual or imagined movement, such as mental rotation, spatial navigation, and spatial tracking, which includes estimating a target's location or trajectory in space [7-9]. Targeting tasks, such as dart throwing or catching a ball, and mental rotation tasks show the largest sex differences with size effect in the range of 1.0 or greater. On the other hand, a female advantage is generally observed for explicit recognition of faces, implicit memory for object recognition, verbal skills related to fluency, episodic memory, and for spatial tasks that require memory of object location [10]. In addition to facial identity, recognition of facial affect is also reported to be better in females [6,11].

Cognitive sex differences have been proposed to result from a variety of factors, including evolutionary pressures [8,12,13]. Males are assumed to have practiced navigational skills related to "hunting" to a greater extent than females, including successful acquisition of food and the use of tools and other skills for viewing of scenes or images from different perspectives [12-14]. The practice of these skills is thought to have translated into a male advantage in performing mental rotation, targeting, and other tasks that require processing of spatial information. On the other hand, females are assumed to have engaged to a greater extent in "gathering" activities, including nurturing of children, which involves the recognition and

expression of emotion. It is hypothesized that such activities led females to excel in emotion recognition, verbal skills, and fine motor tasks. The primary assumption of this evolutionary viewpoint is that cognitive sex differences are quantitative adaptations rather than qualitative differences, and are a function of practice due to established social roles [13].

An alternative explanation proposes that cognitive sex differences arise from genetic or hormonal influences on cognitive development. Contemporary research shows that hormones are particularly important for the development of sex-typical childhood behavior. Male and female fetuses differ in testosterone concentrations in the first trimester when the fetal testes produce a large surge of testosterone that induces genital differentiation that peaks between 12 and 16 weeks of gestation and then falls to female levels during the third trimester until birth [15,16]. At parturition, there is a second testosterone surge in males that peaks within the first two weeks and returns to female levels by 5-6 months later. Male and female levels remain similar for the remainder of development until puberty [17,18]. An effect of these hormonal surges on the organization of perceptual pathways involved in higher cognition is thought to underlie cognitive sex differences [19]. This is supported by a substantial literature showing structural and functional sex differences in the human brain [20].

A commonality in the various explanations of sex differences is that females show a bias for attending to objects and their associated characteristics, whereas males show a bias for attending to object movement and their location

in space. The perception of object features versus object movement/location has been associated with ventral and dorsal stream processing, respectively [21-23]. The dorsal stream extending from the primary visual cortex into posterior parietal areas is primarily involved in localizing and tracking objects in space. More recently it has been suggested that this stream can be subdivided into pathways supporting spatial working memory, visually guided action, and spatial navigation [24]. In contrast, the ventral stream extending from the primary visual cortex into inferior regions of the temporal lobe is involved in object and form recognition. All these pathways operate in parallel, and interact along a hierarchical processing conduit of cognitive elaboration that brings form and motion information together for both conscious and unconscious processing of objects and their movement [23].

The association of sex differences with dorsal and ventral stream processing implies that these differences may actually reflect more the application of strategies and biases involved in processing information, including biases for top- or bottom-up processing [25-30]. Bottom-up information processing is assumed to dominate during spatial tasks such as mental rotation, taking advantage of dorsal stream processing that consistently favor a male viewpoint [5]. Top-down processing is assumed to dominate in verbal and emotional tasks that depend on ventral stream information processing and consistently favor a female viewpoint [31]. Support for these ideas has been provided by a number of studies [25]. Butler et al. [5] compared a group of men and women who showed identical results on mental rotation tasks. Nonetheless, they revealed sex differences in bottom-up and top-down approaches, with the bias for deploying bottom-up information processing attributed to males and top-down information processing attributed to females. McGivern et al. [25] examined biases in both genders using a computer task that measured targeting performance or color shade recognition in situations where the tasks occurred alone or in combination. Results showed that targeting accuracy was significantly better in males compared to females. No sex difference was observed for color shade recognition. However, under the combined condition, male accuracy in targeting, as well as color shade recognition, declined significantly compared to their performance when the tasks were tested alone.

No significant changes were found in female performance.

Based on these patterns, we hypothesize that sex differences are dynamically affected in specific tasks by the changing requirements, which lead to changes in the strategies and biases involved, including those that go against expected ones. In the current study, we investigated spatial tracking as well as emotion recognition in males and females. Tasks were chosen because of the reported superiority for each gender in each of these tasks. We used a computer simulation task similar to that used in the McGivern et al. [25] study to assess differences. Tracking and emotion recognition were compared when performed individually or in combination, with targeting and emotion recognition trials presented in randomized order. Emotion recognition was assumed to reflect an 'object oriented' task, while tracking was assumed to reflect a 'movement oriented' task. Consistent with our previous work [25], we hypothesized that males would show a bias for a bottom-up strategy during the tracking task, while females would use more of a top down strategy for tracking. A bottom-up strategy would give males an advantage in terms of speed and accuracy. However, a top-down strategy, e.g., analyzing moment-to-moment relationships between the moving ball and the environment, would involve a slower, more conscious effort that would give females the advantage in the emotion recognition task. The female bias toward top down processing is likely part of the reason why they generally do more poorly than males in tracking. However, in a competitive situation where time is critical, this bias may be overridden and females would be expected to do better. Face and emotion recognition, on the other hand, rely on ventral stream analysis, which is assumed to be conscious and by definition top-down. Males would be expected to do poorly on such a task because they have to shift between bottom-up and top-down depending on the trial demands. We presented trials at either a slow or fast speed, and hypothesized, based on previous results [25], that the speed of information processing would be reflected in reaction times for both sexes but not in their accuracy performance. That is, we expected that all participants would respond faster to faster speed trials (even during an emotion recognition task where movement *per se* is not necessarily involved) and would reflect an embodied response.

2. MATERIALS AND METHODS

2.1 Participants

Sixty-two undergraduate students (32 females and 30 males with no known neurological disorders; mean age = 21; range = 18-29 yrs.) participated in this study for class credit. Subjects were recruited through SONA, a service that UC San Diego's Psychology Department utilizes to recruit human experimental subjects. Specific demographic information (name, age, sex, major, handedness) was collected from all the participants. The Internal Review Board at the University of California, San Diego approved the protocol. The work has been carried out in accordance with the Declaration of Helsinki for experiments involving humans.

2.2 Experimental Paradigm

Participants were asked to complete a total of 120 trials involving the movement of a ball on the screen. Trials were divided into three conditions (tracking only, emotion recognition only, and combined (tracking+emotion recognition). In each condition, trials occurred at two speeds (slow and fast). In the slow trials, ball moved at a speed of 3.5 cm/s while in the fast trials the ball moved twice as fast, at a speed of 7.0 cm/s. Therefore, the six conditions included tracking slow (TS), tracking fast (TF), emotion recognition slow (ES), emotion recognition fast (EF), combined slow (CS) and combined fast (CF). These conditions, consisting of 20 trials each, were presented in a randomized order within and across participants.

2.2.1 Tracking only task

The EVITA (Evaluation of Variability in Targeting Accuracy) [25] task was used to measure a participant's accuracy in tracking and estimating where a vertically moving ball, with an embedded neutral facial expression (a type of emoticon), would intersect a horizontal line (see Fig. 1A). Participants viewed the ball moving vertically towards a horizontal line. The ball disappeared behind a masking screen, which required the participant to mentally project the vector through the line at the top of the screen that it was intended to intersect. The task was to estimate where the middle of the ball would intersect the line. Participants indicated the intersection point following a 2-sec delay by using a mouse to move a paddle (1.2 cm in length) to the intersection location and clicking on it. For all

trials, participants were allowed 10 seconds to give a response. Accuracy was defined by the average error, or the difference in millimeters in the distance, either to the left or right, between where the participants indicated the ball would have crossed the line and where the ball actually crossed the line according to the trajectory of motion. The larger the average error made the greater the participant's error in judging the correct location of the crossing, and the less accurate the response. Reaction time (RT) to make a decision was calculated from the time the ball moved through the line. The program allowed control of the ball speed, as well as the size of the ball (1.2 cm in diameter), and the size of the masking screen (8.89 cm x 21.59 cm). Ball and screen sizes remained constant throughout the study.

2.2.2 Emotion recognition only task

In the emotion recognition task, the EVITA task was also used to measure participant's accuracy in detecting a change in facial expression. The ball, which contained the same embedded neutral facial expression as used during tracking, changed to a different facial expression (happy, sad, angry) or remained neutral just prior to the ball disappearing behind the masking screen (Fig. 1B). At the end of the trial, participants were presented with four balls containing four different facial expressions (happy, sad, angry, neutral) at the top of the computer display. The appropriate response was selected using a computer mouse to click on the matching response. Accuracy in this task was calculated by summing the number of correct responses. RTs to make a decision were calculated from the time the ball moved through the line to when the click on the facial expression was made.

2.2.3 Combined tracking plus emotion recognition task

This version of EVITA allowed for a combination of the tasks, with the participant unaware of whether the trial would be an 'object oriented' (emotion recognition) or a 'movement oriented' (tracking) task until the trial was underway. It required participants to essentially hold in mind both alternatives, as well as any information processing strategies or biases while the ball moved towards the intersection line. On 50% of the trials, participants were presented an emotion recognition task. Similar to the emotion recognition only task, the ball contained an embedded neutral facial expression that changed to one of three emotional expressions

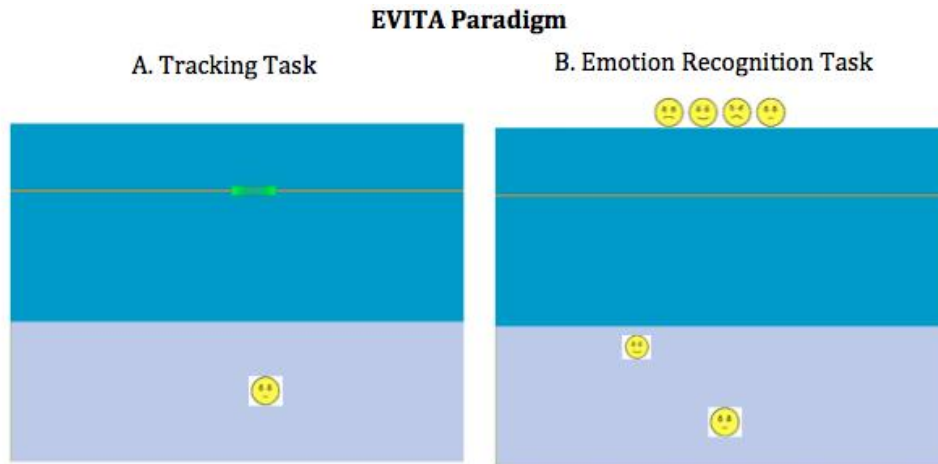


Fig. 1. The Evita Paradigm is shown for the individual Tracking (A) and the Emotion Recognition (B) tasks. In the Tracking task a circular, ball-like emoticon with a neutral expression appears at the bottom of the display and moves vertically towards the top of the display. Approximately at the halfway point the emoticon goes under the masking shade. At the end of the trial a bar appears on the top line and subjects move the bar with the computer mouse to where they predict the emoticon intersected the line. In the Emotion Recognition task, the emoticon changes to a different expression just before it goes under the masking shade. At the end of the trial, four emoticons appear at the top of the screen and subjects click the matching one with the mouse

(happy, sad, angry) or remained neutral before disappearing behind the masking screen (Fig. 1B). A bar with four emotion representations (happy, sad, angry, neutral) would then appear at the top of the display at the end of the trial and the participant would be asked to choose the matching expression. The remaining 50% of the trials were tracking trials where the ball retained a constant neutral facial expression before disappearing behind the masking screen (Fig. 1A). After the ball disappeared behind the masking screen, a green paddle would then appear on the intersection line and the participant was asked to click on the perceived intersection point. Both the sum and average error were calculated for the appropriate trials as this condition included both types of trials presented in a random order.

2.3 Data Analyses

Twenty trials were presented to participants in the targeting or emotion recognition only conditions. In the combined task, twenty trials were presented, with emotion recognition and targeting conditions randomly occurring ten times each. Previous studies [25] have indicated that errors in the targeting condition are significantly

greater on the first trial compared to the mean. Over the subsequent trials, occasional outliers in targeting accuracy or reaction time also occur in some participants, likely due to attentional lapses. Therefore, we adopted the standard procedure reported previously of rank ordering the accuracy scores (distance error), with their associated reaction times, and using the mean of the top 80% in accuracy for analysis. For emotion recognition accuracy, which consisted of a correct response score on each trial, the mean of correct choices and reaction time for all trials was used for analyses, with the exception that reaction times greater than two standard deviations from the mean were eliminated. This resulted in the elimination of less than 1% of the total responses. Data were analyzed using SPSS statistical programs. Accuracy and RTs were analyzed separately using repeated measures ANOVAs with factors of Task (individual, combined) and Speed (slow, fast) as within-subject factors and Sex (male, female) as a between-subject factor. Planned comparisons were conducted using a Bonferroni correction and Greenhouse-Geisser corrections were applied to the degrees of freedom with only the corrected probability values reported.

3. RESULTS

3.1 Accuracy

3.1.1 Tracking

Analysis of the tracking data shows a main effect of Sex, $F(1,60)= 6.4$, $p<0.05$, indicating that males are more accurate, producing an average error of 12.2 mm while females exhibited an average error of 15.9 mm. As shown in Fig. 2A, there was also significant effect of Speed, $F[1,60]= 15.61$, $p<0.01$ showing both males and females making significantly less average errors in the fast (12.81 mm) compared to slow (15.37 mm) tracking condition. This is contrary to our prediction that the embodiment of speed would not correlate with improved accuracy scores. Accuracy analysis also showed a significant interaction effect of Task x Sex, $F[1,60]= 4.97$,

$p<0.05$ (see Fig. 2B). This interaction indicated overall higher accuracy for males in the visual tracking task. However, while male accuracy decreased in the combined task condition (i.e., error distance was increased), female accuracy improved. Table 1 summarizes these average errors in the individual and combined tasks for tracking and emotion recognition trials. It shows that males displayed an average error of 11.4 mm in tracking task alone and 13.1 mm, or slightly worse, in the combined task, resulting in an overall average error of 12.25 mm. In contrast, females exhibited an average error of 15.05 mm in the combined tasks, an improvement over the 16.83 mm in tracking task alone, displaying an overall average error of 15.94 mm across the two tasks. These results indicate that although females are less accurate overall at both tasks compared to

Tracking Trials

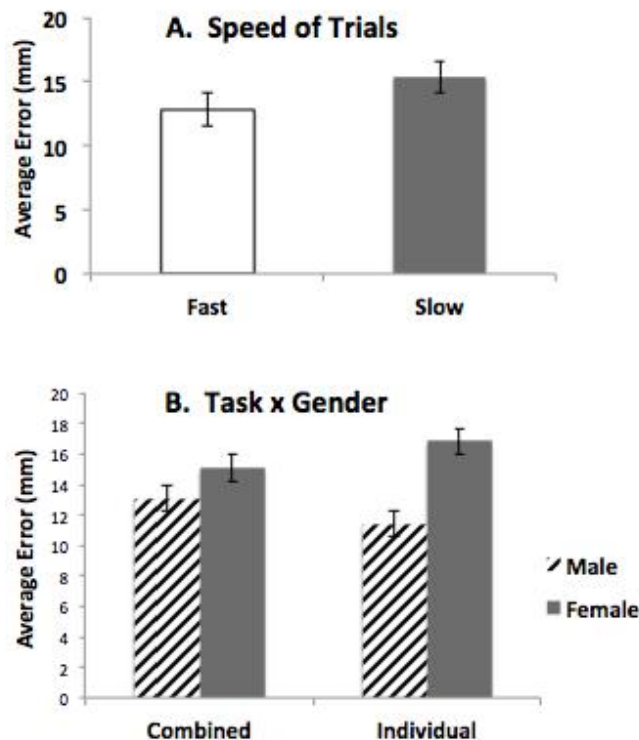


Fig. 2. (A) Histogram showing the average error (mm) for tracking trials in the fast (4.5 cm/s) and slow (9 cm/s) conditions. (B) Histogram showing the average error (mm) of the combined and individual trials for both males and females

males, they do better at multitasking as shown by their higher accuracy in performance in the combined task condition.

3.2 Emotion Recognition

Accuracy in the emotion recognition trials involved summing the number of correct responses (CR). There were no sex differences in the emotion recognition task suggesting a lack of female advantage, which runs counter to the advantage females are presumed to have in emotion processing. As illustrated in Fig. 3A, analysis of CR exhibited a main effect of Speed, $F [1,60]=12.51$, $p<0.01$, such that accuracy in judging facial expressions was better in both genders in the slow (14.33 CR) compared to fast (13.7 CR) speed trials. The advantage of slower speeds may reflect the cognitive load or effort required to process the task. Furthermore, there

was a highly significant main effect of Task, $F[1,60]=5625$, $p<0.00$, showing significantly higher accuracy by all participants in their performance on the emotion recognition condition alone compared to the combined task (Fig. 3B), most likely due to the increased difficulty of the combined task. As summarized in Table 1, accuracy in the emotion recognition task alone was 18.97 CR for males and 19.17 CR for females, while in the combined task it was 8.83 CR and 8.89 CR for males and females, respectively.

3.3 Reaction Times (RT)

3.3.1 Tracking

Table 2 lists reaction times in each condition for males and females. There was a significant main effect of Sex, $F[1,60]= 4.08$, $p<0.05$, with females

Emotion Recognition Trials

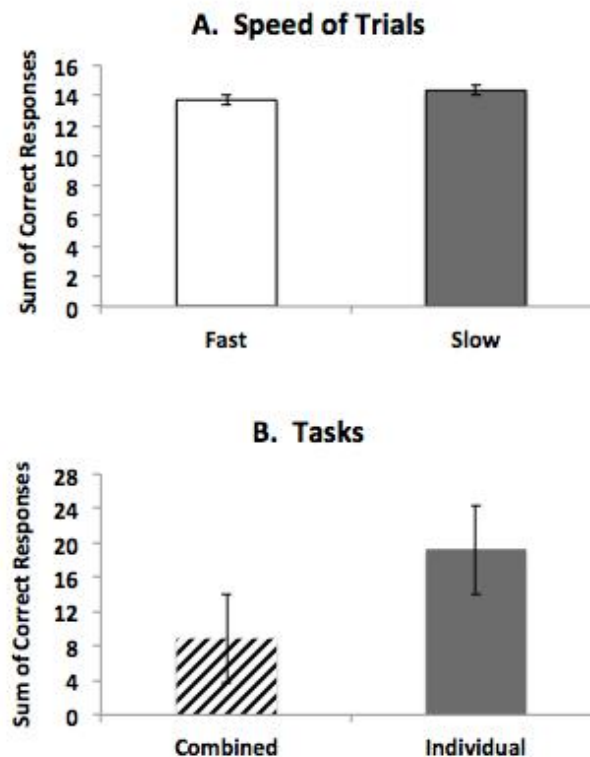


Fig. 3. (A) Histogram showing the sum of correct responses for the emotion recognition trials in the fast (4.5 cm/s) and slow (9 cm/s) conditions. (B) Histogram showing the sum of correct responses in the combined and individual tasks

reacting faster to the stimuli than males (Fig. 4D and Table 2). The average male RT in all conditions was 3957 ms¹ while the average RT for females was 3801 ms, a 156 ms difference. There was also a main effect of Speed, $F[1,60]=7.23$, $p<0.01$ indicating that participants had faster RTs in the fast (3871 ms) compared to slow (3977 ms) speed trials (Fig. 4A), consistent with an embodiment of speed explanation. A significant main effect of Task, $F[3,180] = 21.91$, $p<0.01$ suggested that RTs differed between conditions (see Fig. 4B). Furthermore, as shown in Fig. 4C, a Speed x Task interaction $F[3,180]=6.58$, $p<0.01$ indicated that participants reacted fastest (3691 ms) during the emotion recognition condition, followed by the tracking condition (3887 ms), then tracking in the combined condition (3932 ms), and slowest in emotion

recognition in the combined condition (4186 ms). Pairwise comparisons indicated that all but the combined-tracking versus tracking alone were statistically significant.

Individual analysis of fast and slow speed trials are summarized in Tables 3 and 4 for both sexes. In the fast speed trials, the difference in RT between males and females in the combined trials was 228 ms, 176 ms for tracking only trials, and 141 ms in emotion recognition only trials. In contrast, during the slow speed trials, the difference in RTs for the two sexes in the combined trials was 194 ms, while it was 220 ms for tracking trials, and -24.47 ms in emotion recognition trials. The higher the difference, the longer the males took to complete the task. The differences show that females are faster than

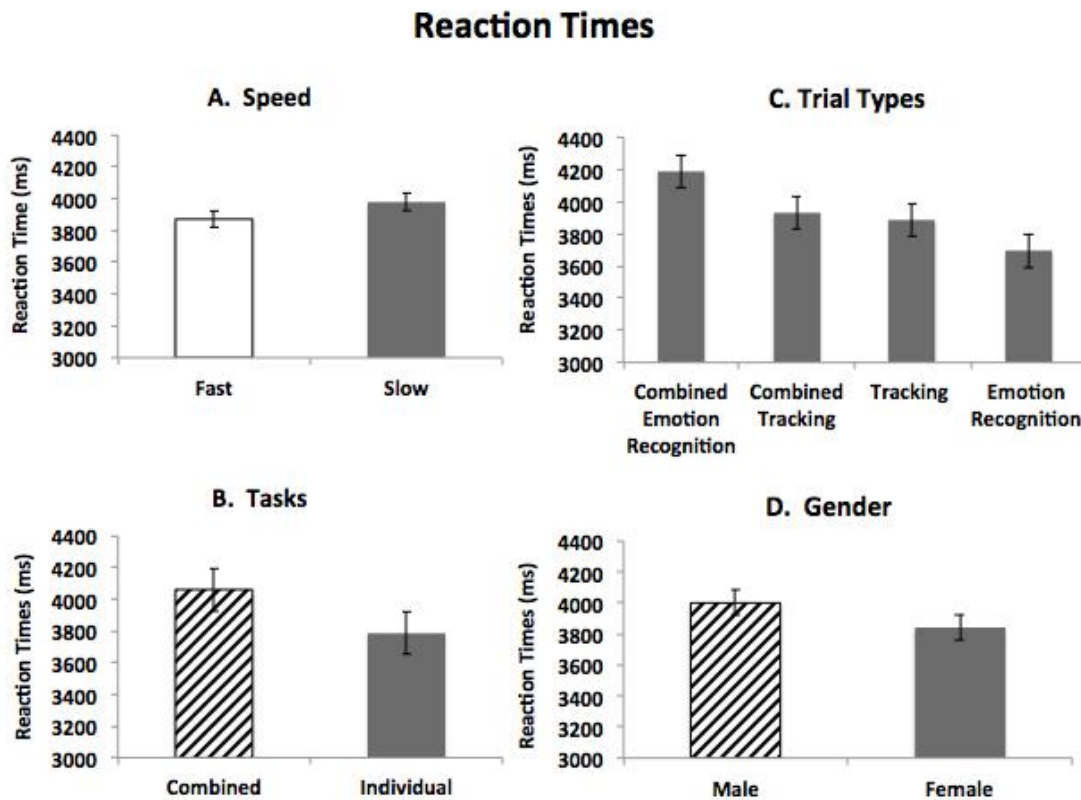


Fig. 4. (A) Histogram showing the mean reaction times for tracking trials in the fast (3.5 cm/s) and slow (7 cm/s) conditions. (B) Histogram showing the mean reaction times in the combined and individual tracking tasks. (C) Histogram of the reaction times for all trial types (combined emotion recognition, combined tracking, tracking, and emotion recognition). (D) Histogram showing the mean reaction times for males and females in tracking trials. Note that all RTs reflect the 2-sec delay imposed before subjects were able to respond

¹Reaction times reflect the additional 2-sec delay imposed before subject are allowed to respond

males in all conditions and speeds other than the slow emotion recognition trials, which is indicated by the negative difference. These effects are illustrated for fast and slow trials in Fig. 5. Male RTs follow more of a linear trend compared to female RTs in the fast trials, with larger differences in the combined tasks compared to the individual tasks. However, that linear difference becomes non-linear during slow trials where females tend to do worse in the emotion recognition during combined trials.

4. DISCUSSION

It has been recognized for some time that cognitive sex differences exist favoring males in the performance of visuospatial tasks [5,9,32-35]. On the other hand, females do better in motor and verbal tasks that require fine and gross motor movements, as well as those involving face and emotion recognition [11,36,6]. The present study investigated sex differences using two distinct cognitive tasks, a visual tracking and an emotion recognition task, performed either

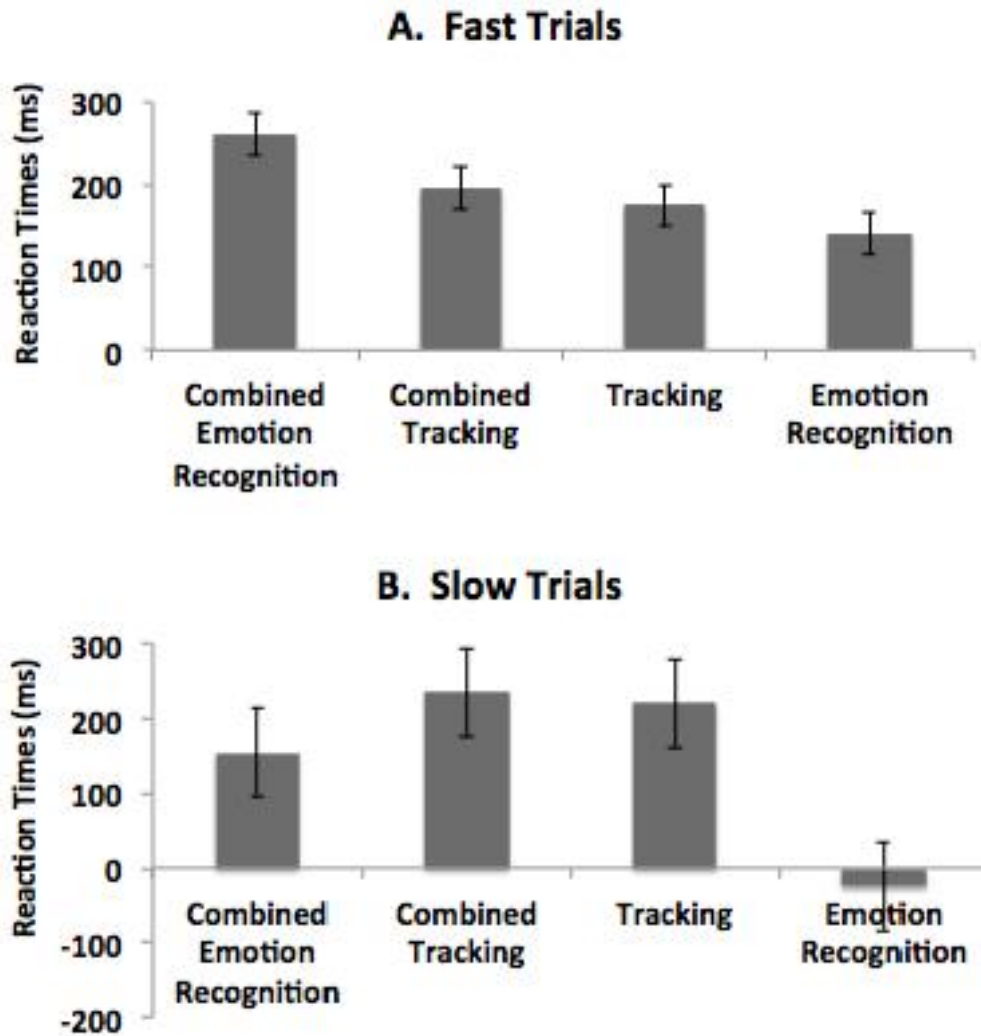


Fig. 5. (A) Histogram showing the differences in reaction times between male and female for fast (7 cm/s) trials in the different conditions (combined emotion recognition, combined tracking, tracking, emotion recognition). (B) Histogram showing the differences in reaction times between male and female for slow (3.5 cm/s) trials in the different conditions (combined emotion recognition, combined tracking, tracking, emotion recognition). A positive difference means that males were slower than females. The negative difference, which occurs in the emotion recognition trials in the slow condition, indicates that males were faster in those trials

Table 1. Accuracy scores for individual and combined trials

	Males	Females
Tracking task*	11.4 mm	16.83 mm
Combined tasks (tracking only)	13.1 mm	15.05 mm
Overall accuracy score (tracking trials)	12.25 mm	15.94 mm
Emotion recognition task**	18.97 CR	19.17 CR
Combined tasks (emotion recognition trials)	8.86 CR	8.91 CR

* Scores reflect average error (the smaller the number the better)

** Scores reflect correct responses (CR: the higher the number the better)

Table 2. RT scores (ms) for individual and combined trials

	Males	Females
Tracking task	3985.68	3788.33
Emotion recognition task	3719.58	3661.34
Combined tasks	4165.08	3953.84
Average reaction time	3956.78	3801.17

Table 3. Accuracy scores for slow and fast and slow trials

	Slow trials		Fast trials	
	Males	Females	Males	Females
Tracking task	13.23 mm	17.52 mm	11.27 mm	14.36 mm
Combined tasks (tracking trials)	14.37 mm	16.43 mm	11.83 mm	13.66 mm
Emotion recognition task	14.15 CR	14.52 CR	13.65 CR	13.75 CR
Combined tasks (emotion recognition Trials)	9.13 CR	9.44 CR	8.53 CR	8.34 CR

Table 4. Reaction Time Scores (ms) for Fast and Slow Trials

	Slow trials		Fast trials	
	Males	Females	Males	Females
Tracking task	4099.67	3880.03	3871.7	3696.63
Emotion recognition task	3725.47	3749.938	3713.7	3572.8
Combined tasks	4187.99	3993.55	4142.17	3914.14

individually or in combination. The tasks were chosen because they have been shown to result in sex-specific advantages. Our findings are consistent with the hypothesis that sex differences reflect more the strategies and biases utilized under different conditions by different individuals. More specifically, we reasoned that sex differences involve differential engagement of dorsal and ventral visual stream, as well as differences in top-down and bottom-up information processing. The data are also supportive of the notion that performance differences can be reduced or eliminated by changing task requirements that mitigate the sex-specific biases. More to the point, our results are consistent with the idea that males perform better in a visual tracking task because they are biased for bottom-up processing, which primarily

engages dorsal stream processing, and that strategy places greater reliance on unconscious, rapid processing. This allows males to perform with greater resolution and speed producing greater efficiency and accuracy in their visual tracking performance. Females are biased towards a top down strategy overall, analyzing moment-to-moment relationships between the moving object and the environment and therefore tend to suffer in tracking performance relative to males. However, in a combined task situation, where one task requires top-down processing, male accuracy suffers while female performance improves. These outcomes indicate that although females are less accurate overall at tracking and emotion recognition compared to males, they do better at multitasking since this may advantage top-down processing.

How do we reconcile a strategy-based performance with structural / functional-based differences? Indeed, sex-dependent differentiation of the brain has been detected at various levels of CNS organization--and thought to be a function of differences in gonadal steroid hormone levels during development [16,37]. For example, sex differences in absolute brain size have been reported and consistently replicated even after correcting for body size [4,38,39]. It is also well established that females have proportionally greater gray matter volume compared to white matter volume [1,40,41]. More specifically, Chen et al. [42] observed increased regional brain volume for men compared to women in midbrain, left inferior temporal gyrus, right occipital lingual gyrus, right middle temporal gyrus and both cerebellar hemispheres. Women showed more gray matter volume in dorsal anterior, posterior and ventral cingulate cortices and right inferior parietal lobule. Of particular relevance to the present study, Keller and Menon [43] showed that, compared to males, females had greater regional density and volume on both dorsal and ventral stream regions. While controversies still exist (see [44], comparisons of male and female brains during resting state-fMRI studies have also generally revealed significant functional asymmetry in brain areas implicated in vision, attention and language [45]. Females exhibit stronger connectivity than males in the posterior cingulate cortex, medial prefrontal cortex and the inferior parietal lobe, but weaker connectivity in the dorsal anterior cingulate cortex (dACC), insula, superior temporal gyrus, superior marginal gyrus and occipital regions [46].

Given that no sex differences have been found in attention and working memory processes *per se* [47], the structural and functional distinctions argue that performance on a task may actually reflect more of the strategies involved in gathering, managing, and allocating cognitive resources to address task demands. That is, the strategies used to manage cognitive resources required to perform verbal and visuospatial tasks are what arises out of the sexual dimorphism reported and is what is most distinct in the two sexes. Indeed, cognitive sex differences may be one way in which evolution capitalized on the capacity of similar brain regions to process information differently between men and women, especially the processing of social signals [11]. Both sexes respond to the complexity and speed of the task by allocating additional cognitive resources, such as attention and effort, during

the trials. Therefore, a theoretical explanation for the performance on these tasks is the need for continuous attention and effort, which produces a depletion of information-processing assets that are not replenished as the task progresses [48]. Therefore, efficiency and speed in processing is necessary to maintain high performance in a task like visuospatial tracking, something that favors the male use of bottom up/dorsal stream processing. Females excel at the combined task because of the need for judicious, perhaps slower, allocation of those resources, which favors top-down/ventral stream processing.

In our study, both males and females reacted faster in fast compared to slow trials. This may be a result of both groups judiciously estimating the complexity of the task and resulting in efficient reactions. This may also occur since fast speed trials can be more cognitively demanding, thus making participants more attentive to the stimuli and resulting in faster reaction times [49, 50]. Another plausible explanation for the relationship between stimulus speed and reaction times involves an embodied response. Embodiment refers to a kind of experience that comes from having a body with sensory and motor capabilities, and which is itself embedded in the larger socio cultural context. It is a mechanism that allows organisms to act in the world, interact with objects and individuals, and understand such interactivity [51,52]. Consistent with this notion is the idea that viewing objects may prime motor responses. It is speculated that observing fast speed trials primes the motor system to respond rapidly, while slow speed trials prime a slower response. This may be why participants made fewer errors in both the individual tracking and combined task conditions in the fast speed compared to the slow speed trials. Our results also show that both groups of participants exhibited greater accuracy in the fast speed tracking trials compared to slow speed trials, thus revealing an overall significant effect of speed. The effect of embodiment of speed on reaction times was expected, but its effects on performance accuracy were not. These results argue that the 'embodied' nature of movement is an integral part of the cognition, even when the task does not require essential information about movement itself. Embodiment may thus help participants judiciously estimate the various conditions and employ and deploy the necessary resources required by the task demands.

There are a number of limitations in the present study that call for caution in the interpretation of

results. The results of the emotion recognition trials indicated significant effects of task and speed in which higher accuracy in terms of correct responses was seen for the individual compared to the combined task and for slow compared to fast trials. However, females showed increased accuracy in slow trials at both speeds and in fast trials for the individual task only compared to males. One explanation for this was suggested by a recent meta analysis [53] that showed that the majority of sex differences favoring women were observed for negative emotion, whereas the majority of the sex differences favoring men were observed for positive emotion. Since 2/3 of the emotion stimuli used in the study were negative (sad, angry), it may have biased the results toward females. However, a few studies suggest that while sex exerts a subtle effect, culture and duration of stay, as well as sex of poser, are shown to be relevant factors for emotion processing [54]. Perhaps a simpler and more pragmatic explanation for the reduced accuracy in the combined task compared to the individual task comes from the theory of divided attention [55-57]. It is plausible that the emotion recognition task is more difficult due to the necessity for perceiving the details of the change in the facial expression of the stimuli. Divided attention argues that any division of attention reduces efficiency and accuracy [49,50]. Since the combined condition requires attention to be focused and allocated on two tasks rather than just one, accuracy for male participants is reduced. However, divided attention cannot account for all the differences, particularly the faster reaction times for both males and females during the emotion recognition task compared to tracking, the improvement in accuracy in females in the tracking trials during the combined condition, nor the expected absence of a sex difference in the emotion recognition task. That is, contrary to our prediction, females do not perform significantly better than males. Rather, both males and females perform with about equal accuracy. We speculate that because males excel at tracking an object in space, their performance may have improved in the emotion recognition task since the participants had to track the trajectory of the motion of the stimulus prior to detecting the change in facial expression. Thus, embedding of the task in this context may have caused improvement in male performance. Second, the females' use of top-down information processing may not have been as advantageous as predicted in this particular task.

The top-down strategy is based on prior knowledge and thus makes information processing easier. Although recognizing changes in facial expression can be learned from day to day interactions with other humans, we may not be as facile in terms of recognizing these changes on artificial faces or emoticons. This lack of exposure and experience with emoticons could have reduced female performance. It is also possible that a combination of these and other explanations could be creating the unexpected results.

5. CONCLUSION

The results of the present study provide new and consistent evidence on the involvement of sex differences seen through the exposure to individual or combined visual tracking and emotion recognition tasks. They indicate that males perform with higher accuracy in visual tracking tasks, although both sexes performed with equal accuracy in the emotion recognition task. The overall results of visual tracking support the prediction that males would excel at that task, whereas the results of the emotion recognition portion did not align with the prediction that females would excel at the task. A partial explanation may be the type of stimuli used in this study (emoticons versus real faces). Our study also revealed unexpected results in terms of participants exhibiting higher accuracy, as well as faster response times, in fast tracking trials. We take this to mean that embodiment of movement is an integral part of the cognition, even when the task does not require essential information about movement itself. The results are congruent with previous studies indicating correlations between the dorsal, ventral and top-down, and bottom-up information processing with cognitive sex differences. Additional investigations are needed that show sex differences with brain imaging techniques, namely electroencephalography (EEG), magnetoencephalography (MEG), and functional magnetic resonance imaging (fMRI) using more realistic human faces. Additional studies could also expand the individuals of various age groups or populations that identify as different sexual orientations and identities.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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