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Gender Differences in Multitasking Reflect Spatial Ability

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Abstract

Demands involving the scheduling and interleaving of multiple activities have become increasingly prevalent, especially for women in both their paid and unpaid work hours. Despite the ubiquity of everyday requirements to multitask, individual and gender-related differences in multitasking have gained minimal attention in past research. In two experiments, participants completed a multitasking session with four gender-fair monitoring tasks and separate tasks measuring executive functioning (working memory updating) and spatial ability (mental rotation). In both experiments, males outperformed females in monitoring accuracy. Individual differences in executive functioning and spatial ability were independent predictors of monitoring accuracy, but only spatial ability mediated gender differences in multitasking. Menstrual changes accentuated these effects, such that gender differences in multitasking (and spatial ability) were eliminated between males and females who were in the menstrual phase of the menstrual cycle but not between males and females who were in the luteal phase. These findings suggest that multitasking involves spatiotemporal task coordination and that gender differences in multiple-task performance reflect differences in spatial ability.

Keywords

cognitive processes, sex differences, visuospatial ability, divided attention

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Many daily activities, such as preparing a breakfast and driving in heavy traffic, require scheduling and interleaving of multiple tasks within a limited time frame (e.g., Burgess, Veitch, de Lacy Costello, & Shallice, 2000; Craik & Bialystok, 2006; Logie, Trawley, & Law, 2011; Salvucci & Taatgen, 2008). Following the recent development of new forms and new uses of media, demands and possibilities for media multitasking (i.e., using different forms of media in conjunction with each other) have become increasingly prevalent, especially among the young (Ophir, Nass, & Wagner, 2009; Roberts, Foehr, & Rideout, 2005). Several studies have also suggested that the amount of time people spend multitasking has increased during past decades and that these effects have been accentuated for women in both their paid and unpaid work hours (e.g., Bianchi, Milkie, Sayer, & Robinson, 2000; Offer & Schneider, 2011; Sayer, England, Bittman, & Bianchi, 2009). For example, Offer and Schneider (2011) reported that mothers spend 10 more hours a week multitasking compared with fathers and that these additional hours are mainly related to time spent on housework and child care.

Despite the ubiquity of everyday requirements to multitask, individual and gender-related differences in multitasking have gained minimal attention in research (see also Hambrick, Oswald, Darowski, Rench, & Brou, 2010; Watson & Strayer, 2010). Although media reports and popular books (Fisher, 1999; Pease & Pease, 2003) suggest that women are better multitaskers than men are, the scientific evidence for gender differences in multitasking is nonexistent. For example, Hambrick et al. (2010) completed an extensive search of the literature but "could not find a single scientific report to support this view" (p. 1164).

It is reasonable to assume that individual and gender-related differences in multitasking emanate at least from two sources. First, multiple-task performance reflects domain-specific differences in how well an individual can perform a component task in isolation. Highly trained experts, such as pilots (e.g., Loukopoulos, Dismukes, & Barshi, 2009; Wickens, 2008), are skillful multitaskers in their domains of expertise because they have extensive experience with the component tasks. From this perspective, observations suggesting that women are better multitaskers than men may reflect gender differences in task-specific experience (e.g., child care).

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The second source of variability, which was the primary focus of this study, reflects individual differences in the ability to coordinate component tasks, independent of task-specific skills and experiences. From this perspective, the causes of gender-related differences in multitasking should not be limited to structural biases in the work environment (concerning, e.g., prior experience and expertise) but should extend to differences in the actual cognitive capacity for coordinating and monitoring multiple tasks.

Although these higher-order functions of multitasking are assumed to be closely related to executive functioning, the specific mechanisms underlying individual differences in multiple-task performance are not well understood (but see Meyer & Kieras, 1997; Salvucci & Taatgen, 2008; Shallice & Burgess, 1991; Watson & Strayer, 2010). The present study tested the hypothesis that the higher-order ability to coordinate multiple tasks reflects individual differences in two basic cognitive functions—first, the ability to maintain and update multiple task goals (executive functioning, measured with tests of working memory updating), and second, the ability to coordinate spatial relations (spatial ability, measured with tests of mental rotation).

In this study, I examined these hypotheses under experimental conditions that emphasized the more abstract characteristic of multitasking while attempting to minimize individual and gender-related differences in domain-specific skills. To this end, the study involved four component tasks that were similar and rather simple, but multitasking by performing the tasks in combination required a high degree of task coordination. Specifically, in two experiments, participants monitored three digital "clocks" (counters) that were identical in that they displayed forward-running digits. In this *counter task*, participants responded whenever a counter showed a target reading, which was defined by a simple rule. Earlier work involving a single monitoring task revealed gender differences neither in response accuracy nor in monitoring frequency (e.g., Ceci & Bronfenbrenner, 1985; Forman, Mäntylä, & Carelli, 2011; Mäntylä, Carelli, & Forman, 2007; Mäntylä, Del Missier, & Nilsson, 2009).

Finally, to increase overall task demands, I had participants complete a background task while monitoring the counters. This *name-back task* also required monitoring: In this task, participants viewed a list of first names that appeared one at a time on a computer screen and had to respond when a target name was the same as the name presented four steps back. On the basis of earlier work (e.g., Kane, Conway, Miura, & Colflesh, 2007; Miyake et al., 2000), this type of *n*-back task was assumed to reflect the monitoring and updating component of executive functioning. It should be noted that neither behavioral nor brain-activation data have shown gender differences in *n*-back performance (Schmidt et al., 2009).

In Experiment 1, I examined the hypothesis that multitasking, as measured with the four component tasks (the three counter tasks and the name-back test), reflects individual differences in executive functioning. This hypothesis is consistent with findings from earlier studies involving frontal-lobe patients (Shallice & Burgess, 1991) and healthy adults (e.g., Watson & Strayer, 2010). Earlier work in the context of prospective memory also suggested that (single-task) monitoring is mediated by individual and developmental differences in executive functioning (Forman et al., 2011; Mäntylä et al., 2007, Mäntylä et al., 2009).

In Experiment 2, I investigated the hypothesis that executive functioning and spatial ability are independent predictors of task performance but that only spatial ability contributes to gender differences in multitasking. This hypothesis was based on the assumption that most goal-directed tasks, including everyday multitasking, involve temporal processing. One strategy for handling these temporal complexities might be to represent "time in space" (Casasanto & Boroditsky, 2008) by recoding the temporal pattern of deadlines and task goals in spatial terms. Given this *spatiotemporal hypothesis* (see Experiment 2 for details), and considering that men perform better than women in many spatial tasks (Linn & Petersen, 1985; Voyer, Voyer, & Bryden, 1995), individual differences in spatial ability (but not in executive functioning) were expected to mediate gender-related differences in multitasking.

Experiment 1

Method

Participants. Seventy-two adults (36 females, 36 males) between 19 and 40 years of age (mean age: females = 27.59 years, males = 28.35 years) participated in the study in return for partial course credit or payment. A majority of the participants were students of Umeå University. All participants were experienced computer users, but none of them played computer games for more than 2 hr per day.

Tasks. Multitasking was assessed with a computerized task comprising four component tasks. In the three counter tasks, digital clocks, or counters, appeared on the computer screen. Participants pressed the space bar whenever one of the counters showed a target reading, which was defined by a simple rule (see the Procedure section). They could monitor each counter by pressing a specific key, whereupon the corresponding counter appeared for 2 s. To prevent the three tasks from being handled as a unitary task, I ran the counters at different rates (3.60 s, 2.72 s, and 2.40 s per item, respectively).

In the name-back task, participants viewed a series of common Swedish first names, which were presented above the three counters at the rate of 2 s per item. The stimuli comprised 40 targets (20 male names and 20 female names) and 360 nontarget names. None of the nontargets were repeated in the stimulus list.

Executive functioning was assessed with the *letter-memory task*, a measure of individual differences in the updating component of executive functioning (Miyake et al., 2000). In this task, 12 random sequences of letters were presented at the rate of 2 s per item. The length of each sequence varied from 5 to 9 letters. At the end of each sequence, participants were asked to report the last four letters.

Procedure. Each participant was tested individually during a 45-min session. After completing a background questionnaire, participants completed a multitasking session in which they performed the name-back and counter tasks. In the counter tasks, participants monitored each counter for target readings, which were defined by three rules. Specifically, the experimenter instructed participants to press the space bar when the last two digits of Counter 1 were a multiple of 11, when the last two digits of Counter 2 were a multiple of 20, and when the last two digits of Counter 3 were a multiple of 25. The displays for the three counters were in different colors (green for Counter 1, blue for Counter 2, and red for Counter 3). Participants could view the reading of each counter whenever they wanted by pressing a key in the same color, after which the counter would be visible for 2 s. Responses were considered correct if they were within 1 digit of the target (e.g., 19, 20, and 21 would be considered correct responses if the target was 20).

For the name-back task, participants were instructed to press a key whenever the name on the screen was the same as the one presented four names earlier in the sequence. Participants were informed that the three counter tasks and the name-back task were equally important and that the tasks were running at different rates. After receiving written instructions, participants completed practice trials of the name-back task, followed by a combined practice session with all four experimental tasks. After the experimenter had confirmed that participants understood the instructions, the participants completed the multitasking session for 20 min, followed by the letter-memory task. This task also included written instructions and a separate practice phase.

Results

In both experiments, multitasking performance was based on performance of the four component tasks. The dependent measures of the counter tasks were response accuracy (maximum number of correct responses = 72) and monitoring frequency, respectively. Because the latter measure did not show any systematic effects, accuracy was the primary dependent variable in the analyses for both experiments. Number of hits and false alarms were the dependent measures for the name-back task, and number of correct responses was the primary measure for the letter-memory task (see also Del Missier, Mäntylä, & Bruine de Bruin, 2010).

Consistent with our hypothesis, results showed that participants with efficient updating functions were better multitaskers than participants with less-efficient control functions, as indexed by accuracy in the counter task ($r = .46$, $p < .01$) and in the name-back task ($r = .32$, $p < .02$). The second main finding of Experiment 1 was that males (mean proportion correct = .85) outperformed females (mean proportion correct = .74) at multitasking, as indexed by accuracy in the counter task, $F(1, 70) = 6.25$, $\eta_p^2 = .08$, $p < .01$.

As shown in Figure 1, the gender difference in accuracy favored men by about 10% across the three counter tasks. This difference was not due to a trade-off between accuracy in the counter tasks and in the background (name-back) task, given that both men and women identified about 38% of the targets in the name-back task (with no differences in false alarms). Furthermore, gender differences in counter-task accuracy were not related to differences in monitoring frequency ($F < 1$). Females (mean proportion correct = .52) performed somewhat better than men (mean proportion correct = .48) in the letter-memory task, but this difference was not reliable ($F < 1$).

Experiment 2

The findings of Experiment 1 suggested that individual differences in executive-control functions contribute to differences in the ability to coordinate performance of multiple tasks, but that some factor (or factors) other than working memory updating mediated gender differences in multitasking. The aim of Experiment 2 was to examine one of these factors by testing the hypothesis that multitasking ability reflects individual differences in spatial ability.

This hypothesis was based on the assumption that most goal-directed tasks, including everyday multitasking, are temporal in that scheduling, monitoring, and task interleaving take place in a (relative or absolute) time scale (e.g., first A, then B) and that coordinating multiple goals and deadlines requires a high degree of cognitive control (as suggested by the findings of Experiment 1). One way to handle these complexities might be to represent the temporal pattern of deadlines and task goals in spatial terms.

As a support for this line of reasoning, several studies suggest that people use space to represent time in complex task

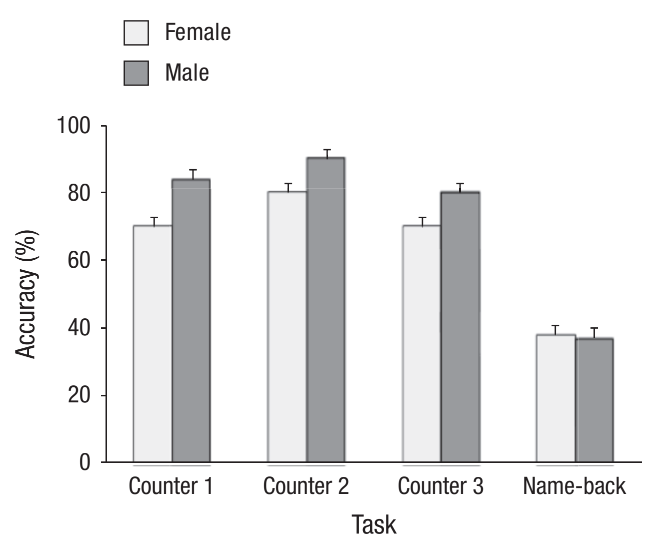

Fig. 1. Results from Experiment 1: accuracy as a function of gender and task. Error bars represent standard errors of the mean.

conditions (Carelli, 2011; Carelli & Forman, 2011; Casasanto & Boroditsky, 2008). For example, Carelli and Forman (2011) showed that even preschool-aged children were able to represent complex (asynchronous) temporal patterns by using spatial "timelines" as retrieval aids. Furthermore, considering that men are better than women at performing many tasks of spatial ability (Linn & Petersen, 1985; Voyer et al., 1995), these effects may contribute to gender differences in multitasking. To test this hypothesis, I had male and female participants complete the same multitasking session used in Experiment 1, along with tests of spatial ability and spatial working memory.

A corollary prediction tested in Experiment 2 was that men's superiority at multitasking should be eliminated when gender differences in spatial ability are minimized. To this end, I related spatial ability to multitasking performance by examining its variation across the female menstrual cycle. Changes in the menstrual cycle are systematically related to changes in spatial ability, such that women score lower on spatial tasks when they are in the late follicular and subsequent luteal phases of their cycle than when they are in the menstrual and early follicular phases (Hampson, 1990; Hausmann, Slabbekoorn, Van Goozen, Cohen-Kettenis, & Güntürkün, 2000). On the basis of these findings and the proposition that individual differences in spatial ability mediate multitasking, I predicted that gender differences in multitasking might be accentuated in the luteal phase of the menstrual cycle and eliminated in the menstrual phase.

Method

Participants. Eighty-eight Stockholm University undergraduates (48 females, 40 males) between 19 and 43 years of age (mean age: females = 25.64 years, males = 26.17 years) participated in the study in return for partial course credit or payment. Individuals who were under hormonal treatment, used hormonal contraceptives, or were pregnant were not included in the study. Most of the female participants completed the test session while they were in either the menstrual or the luteal phase of their menstrual cycle. Specifically, 20 females (mean age = 25.15 years) reported that they were in the menstrual phase (defined as 2–3 days before the predicted menstruation or during the first week of the cycle), and 20 females (mean age = 25.13 years) reported that they were in the luteal phase (defined as 2–3 days before ovulation or during the week of predicted ovulation). The remaining 8 females provided insufficient information about their menstrual status and were not included in analyses in which female participants' menstrual phase was a factor. The results for 1 of these 8 participants were also excluded from all analyses because of poor performance in the counter task.

Tasks and procedure. The multitasking session was the same as that in Experiment 1. Spatial ability was assessed with the Vandenberg and Kuse Mental Rotations Test (MRT; Peters et al., 1995; Vandenberg & Kuse, 1978). After receiving written instructions and completing four practice problems, participants were given 3 min to complete one set of problems, followed by a short break, after which they completed another set. The dependent measure of this task was number of correct responses. Responses were scored such that participants were given a point only if both stimulus figures that matched the target figure were identified correctly (maximum number of correct responses = 24 for both sets).

Executive functioning was assessed with the matrix-monitoring task (Salthouse, Atkinson, & Berish, 2003). In this task, two 4 × 4 matrices appeared on the computer screen, separated by a line. A black dot then appeared in one of the cells in both matrices. After 3 s, the matrices disappeared, and two sequences of three arrows appeared to indicate the movement of the dot in either the upper or the lower matrix. Finally, one matrix reappeared either above or below the line, with the dot in one of the cells. Participants decided whether the position of the dot was the same as or different from the final position indicated by the arrows. The main task comprised 12 trials, and the number of correct responses was the dependent measure.

As in Experiment 1, participants were tested individually during a 45-min session. After completing a brief background questionnaire, half of the participants first completed the MRT, which was followed by the multitasking session and the matrix-monitoring task. The remaining participants completed the tasks in the opposite order. (Analyses revealed no effects of task order, so results are not included here.)

Results

The correlation data summarized in Table 1 suggest that multitasking was related to individual differences in both spatial ability and executive functioning. Multiple regression analysis showed that MRT ($\beta = 0.41$, $p < .01$) and matrix monitoring ($\beta = 0.21$, $p < .05$) were independent predictors of counter-task accuracy, $r = .51$, $F(2, 84) = 14.43$, $MSE = 0.02$, $p < .01$.

Replicating the findings of Experiment 1, males were better at multitasking than were females. As shown in Figure 2, males outperformed females both in terms of counter-task

Table 1. Pearson Correlations for Multitasking, Spatial Ability, and Executive Functioning (Experiment 2)

Measure	1	2	3
1. Counter task	—		
2. Name-back task	.26*	—	
3. MRT	.41**	.23*	—
4. Matrix-monitoring task	.39**	−.03	.27*

Note: Performance on the counter tasks and name-back task served as an index of multitasking ability. Spatial ability was measured with Vandenberg and Kuse's (1978) Mental Rotations Test (MRT). Executive functioning was measured with the matrix-monitoring task.
*$p < .05$. **$p < .01$.

accuracy, $F(1, 85) = 15{,}19$, $MSE = 0.01$, $\eta_p^2 = .17$, $p < .01$, and name-back-task accuracy, $F(1, 85) = 8.83$, $MSE = 0.07$, $\eta_p^2 = .08$, $p < .01$ (with no between-gender differences in rates of false alarms). Furthermore, a significant gender effect was observed in mental rotation, $F(1, 85) = 28{,}77$, $MSE = 0.02$, $\eta_p^2 = .23$, $p < .01$, and, as shown in Figure 2, these effects paralleled those observed for multitasking. Finally, males showed somewhat better performance in the matrix-monitoring task (mean proportion of correct responses = .80) than did females (mean proportion of correct responses = .78), but this difference was not significant ($F < 1$).

Mediational analysis with a Sobel test indicated that the gender difference in multitasking was fully mediated by spatial ability ($z = 2.75$, $SE = 0.02$, $p < .001$). Specifically, the direct effect of gender on counter-task accuracy ($\beta = 0.39$, $p <$ 01) was significantly reduced when MRT performance was included as a mediator ($\beta = 0.21$, $p < .10$). Within-gender associations between counter-task and MRT performance also supported the hypothesis that individual differences in spatial ability contribute to multitasking, with significant correlations for both males ($r = .47$, $p < .01$) and females ($r = .31$, $p < .05$).

Finally, to test a more specific prediction of the spatiotemporal hypothesis, I related individual differences in spatial ability to multitasking performance by examining their covariation across the female menstrual cycle. As shown in Figure 3, gender differences in both multitasking and spatial ability were related to changes in the menstrual cycle. First, consistent with results from earlier work, the MRT data showed a main effect of group, $F(2, 77) = 11.93$, $MSE, = 0.02$, $\eta_p^2 = .25$, $p < .01$, and Bonferroni-corrected post hoc tests indicated significant differences among all three groups (men vs. luteal-phase females vs. menstrual-phase females). Furthermore, an analysis of variance (ANOVA) on the counter-task data showed a main effect of group, $F(2, 77) = 10.04$, $MSE = 0.01$, $\eta_p^2 = .22$, $p < .01$, and separate post hoc tests indicated a highly

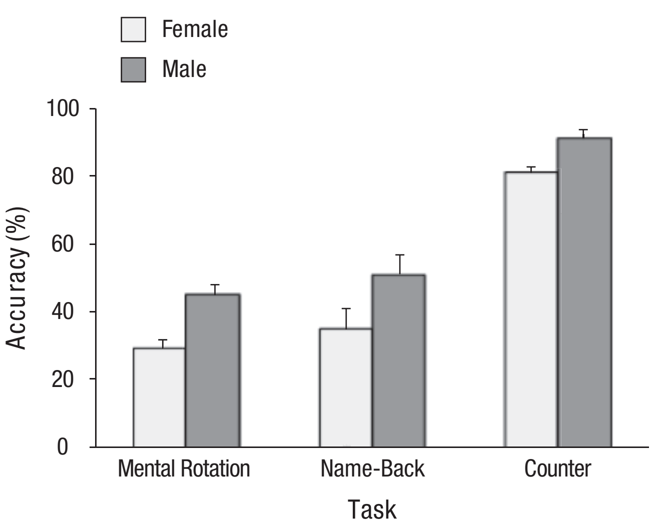

Fig. 2. Results from Experiment 2: accuracy as a function of gender and task. Error bars represent standard errors of the mean..

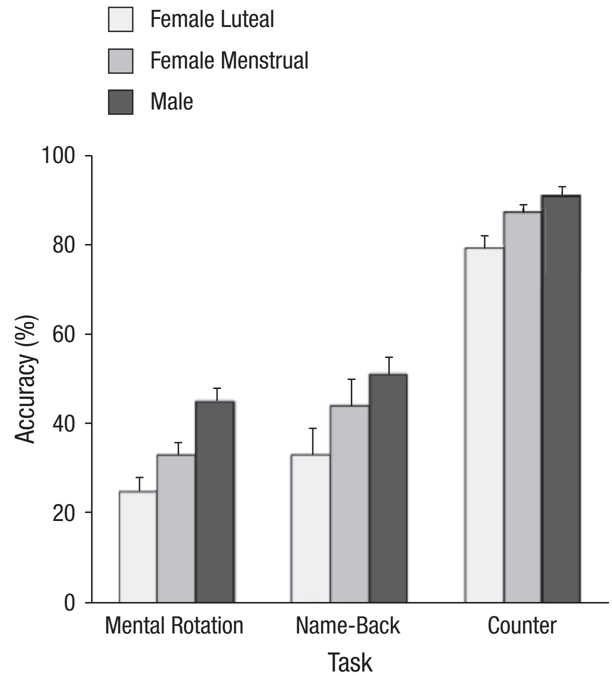

Fig. 3. Results from Experiment 2: accuracy as a function of group and task. Error bars represent standard errors of the mean..

significant difference between males and females who were in the luteal phase of their menstrual cycle ($p < .01$), whereas the difference between males and females who were in the menstrual phase of their cycle was not significant. Finally, the name-back-task data showed the same pattern of results, $F(2, 77) = 3.25$, $MSE = 0.07$, $\eta_p^2 = .08$, $p < .01$. Taken together, these findings suggest that female participants' monitoring accuracy was accentuated during the menstrual phase of their cycle and that changes in spatial ability across the menstrual cycle mediated gender differences in multitasking.

General Discussion

In this study, I examined individual and gender-related differences in multitasking by using component tasks that were relatively simple and gender fair but whose combined performance required a high degree of task coordination. The main finding of the study was that accuracy in monitoring multiple tasks reflected individual differences in both spatial ability and executive functioning but that only spatial ability contributed to gender differences in monitoring accuracy. Mediational analyses showed that men's superior ability to multitask, measured in terms of counter-task and name-back-task accuracy, was eliminated when individual differences in spatial ability (but not in working memory updating) were controlled for. Experiment 2 provided additional support for this hypothesis by showing that gender differences in multitasking (and spatial ability) were eliminated among females who were in the menstrual, but not the luteal, phase of their menstrual cycle.

Taken together, these findings suggest that multiple task monitoring involves spatiotemporal task coordination and that gender differences in multitasking reflect differences in spatial ability.

This study constituted the first explicit test of the popular assumption of gender-related differences in multitasking. Demands involving the scheduling and interleaving of multiple activities have become increasingly prevalent, especially for women. This fact, in combination with media reports and popular books, has contributed to less-well-grounded assumptions about females' superiority at multitasking. The present findings suggest that these assumptions and actual differences between men and women in time-use patterns do not directly translate to a superior female capacity to handle multiple tasks.

The findings of this study were consistent with the spatiotemporal hypothesis of multitasking, but several limitations of the study should be acknowledged. First, because the primary focus of this study was individual and gender-related differences in the basic mechanisms of higher-order task coordination, it was necessary to use (gender-fair) test conditions in which the role of domain-specific skills and experiences were minimized.

Furthermore, although most everyday multitasking may involve a great deal of spatiotemporal processing, it is reasonable to assume that these demands are domain specific. A central assumption of the spatiotemporal hypothesis introduced here is that gender differences in multitasking are expected when the demands on temporal coordination are relatively high. In most dual-task conditions, these demands are low and less dependent on spatial abilities than are multiple tasks that may require coordination of a complex pattern of temporal contingencies. This line of reasoning is also consistent with evidence from earlier studies showing no gender-related differences in dual-task conditions. Further work examining the spatiotemporal hypothesis proposed here should provide a closer analysis of specific components of spatial ability, as well as other factors (e.g., spatial anxiety) that may mediate individual differences in these skills.

Another limitation of the study is that both experiments involved relatively restricted time frames and predictable target events (in the counter tasks). The term *multitasking* is a loosely defined construct that covers a wide spectrum of activities and time frames. Multitasking in some conditions may require very narrow deadlines (e.g., air traffic control), whereas other types of multitasking (e.g., household activities) may impose lower demands on spatiotemporal processing because of more-generous time windows.

It is reasonable to assume that, like most goal-directed tasks, everyday multitasking reflects different mixtures of task-independent cognitive functions (e.g., components of executive functioning and spatial processing) and more domain-specific skills and strategies. From this perspective, individual differences in multitasking should be considered in relative terms, given that some conditions may show reduced or even reversed gender differences because of task-specific constraints and strategies. An interesting avenue for future research would be to investigate individual and gender-related differences in multitasking in relation to different levels of task complexity and compensatory mechanisms.

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Declaration of Conflicting Interests

The author declared that he had no conflicts of interest with respect to his authorship or the publication of this article.

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