2017 HAWAII UNIVERSITY INTERNATIONAL CONFERENCES
SCIENCE, TECHNOLOGY & ENGINEERING, ARTS, MATHEMATICS & EDUCATION JUNE 8 - 10, 2017
HAWAII PRINCE HOTEL WAIKIKI, HONOLULU, HAWAII

GENDER, AND PRACTICE FACTORS ON LEARNING OF A VISUAL AIMING, AND TARGET-ACQUISITION TASKS

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Gender, and Practice Factors on Learning of a Visual Aiming, and Target-Acquisition Tasks

Synopsis:

This paper demonstrates that current social, cultural, and task contexts, not the motor control and learning deficiencies affect women's performance in complex visual motor tasks. The results showed that, although males' performance appeared to be better overall (largely due to small differences accumulates) across conditions, women performed as well as men and even better for accuracy when practicing the altered task factors simultaneously in a complex visual motor task. Therefore, gender differences in performing visual motor tasks should not be exaggerated because they may carry a greater risk of promoting gender-based discrimination in the workplace. However, we should not ignore differences just because the current social, cultural, and task contexts in real-life motor skills are advantageous to males and may discourage women from becoming involved in performing certain visual motor tasks.

Abstract

Gender stereotyping related to learning certain skills may discourage women from enrolling in STEM fields and holding certain occupations. Therefore, this study explores the roles of gender, training and testing conditions on the learning of a novel stimulus response compatibility (SRC) task. Participants (20 men, 16 women of college age) directed a cursor onto a circular target on a monitor as quickly as possible. A joystick directed cursor movements, having either position or velocity control order and compatible or incompatible mapping, depending on the testing conditions. Overall, male participants' movements were faster and more accurate than movements of the female participants. However, female participants' performance did not significantly differ from that of the male participants when the participants practiced two task factors simultaneously and females benefited significantly more than males from the practice. The testing conditions (context) significantly contributed to the performance differences in female participants. In conclusion socioeconomic and cultural values and subsequent gender roles influence performance differences between men and women in a novel stimulus response compatibility (SRC) task. Women should be given more freedom, encouragement and positive reinforcement to explore and participate in certain visual spatial tasks during early childhood.

Keywords: Gender differences; Stimulus response compatibility; Learning and skill acquisition; Training; Adaptation; Controls and input devices

The roles of gender, and practice factors on learning of an object controlling, visual aiming, and target- acquisition tasks

Certain occupations are still considered to be more appropriate for men rather than women because of the gender stereotyping of jobs and the belief in innate gender differences (Shinnar, Giacomin, & Janssen, 2012). Although today more women are enrolled in science, technology, engineering and math (STEM) fields, the number of women still continues to lag in bioengineering, mechanical, and civil engineering and materials science. Women still remain significantly underrepresented in computer (27 percent), engineering (13 percent) and field specializations, such as mechanical engineering (6 percent) despite the fact that significant progress has been made since 1970s (Blume-Kohout, 2014). This is because gender stereotyping related to learning certain skills may discourage women from enrolling in STEM fields and holding certain occupations. Therefore, this study explores the roles of gender, training and testing conditions on the learning of a novel stimulus response compatibility (SRC) task.

A number of studies have shown that men were faster, more accurate and more efficient than women when performing visual motor tasks related to real life experience (Grantcharov, et al., 2003; Kass, Ahlers, & Dugger, 1998; Schueneman, et al., 1985; Thorson, Kelly, Forse, & Turaga, 2011). A previous study has shown that men had a significantly lower error rate than women when estimating the orientation angle of a ship viewed on a submarine periscope simulator (Kass, et al., 1998). Likewise, among medical students and resident surgeons, males performed better than females in “Minimally Invasive Surgical Training”; males were faster, more accurate and more efficient than their female counterparts (Grantcharov, Bardram, Funch-Jensen, & Rosenberg, 2003; Rosser, Cuddihy, Gentile, Klonsky, & Merrell, 2007; Schueneman, Pickleman, & Freeark, 1985; Thorson, et al., 2011).

This is thought to be because: a) men are believed to be more involved in the human-machine interaction process (Barnett, Van Beurden, Morgan, Brooks, & Beard, 2010; Feng, Spence, & Pratt, 2007; Garcia, 1994; Griffith, Voloschin, Gibb, & Bailey, 1983; Levine, Vasilyeva, Lourenco, Newcombe, Huttenlocher, 2005); and b) receive greater freedom, encouragement and positive reinforcement than women to hold certain occupations, and to explore and participate in certain activities related to movement speed, object controlling, visual aiming, and target- acquisition tasks during early childhood (Grantcharov, et al., 2003; Hyde, 2005; Kass, et al., 1998; Sanders, 2013; Schueneman, et al., 1985; Shinnar, et al., 2012; Subrahmanyam, & Greenfield, 1994; Tzuriel, & Egozi, 2010).

Several practical applications may result from the present study including: 1) showing the differences in male and female performance of the task contexts during the learning of a complex visual directional SRC task; 2) decreased training time for new complex visual motor tasks in men and women; and 3) discovery of new learning strategies by exploring adaptation effects that may differ between men and women.

Method

Participants

A total of 36 young adults, 20 male and 16 female, with an average age of 23 years (SD=2.73 years) volunteered as test participants. No participant was tested when he/she appeared to be tired, fatigued, or not mentally alert. Participants visited the laboratory once where they were tested for approximately two hours. Participants had no information about the experiment and its procedures until the day they were tested. All participants were tested according to human subjects' procedures that were approved by the Institutional Review Boards (IRB) and participants' informed consent was obtained.

Materials

The experimental task was to guide a cursor (a white circle about 1 cm in diameter) onto a circular target (a colored circle about 2.5 cm in diameter) on a computer screen as quickly as possible (see Figure 1). These movements were made with a hand-held joystick having either compatible (joystick and cursor movements are in the same direction) or incompatible (joystick and cursor movements are reversed) task with position or velocity control order, depending on the test.

Position control order. A task such as guiding a cursor onto a target on a screen by using a joystick is relatively easy to execute if the control system is based on position (zero) control order. This is because there is no lag between the joystick and cursor movements; the position of the cursor corresponds to the position of the joystick. Thus, a single unidirectional movement will cause a single unidirectional output motion in position control order. Therefore, position control order tasks are considered natural and well-learned.

Velocity control order. As the control order increases, it becomes more difficult to execute such tasks because the visually guided hand movements are disrupted by altered input and output between the control and display. For example, in first order (velocity) control, the position of the control corresponds to the velocity of the controlled object. Therefore, bi-directional movement is needed to cause a unidirectional output motion on the screen.

Dependent Variables

Four dependent variables were used to measure the performance of each participant.

Reaction Time (RT): This measures the capabilities of the participant to anticipate and initiate the required action. Therefore, RT represents the interval between a target appearing on the monitor and hand, joystick, movement initiation.

Movement time (MT): This indicates how quickly the participant moved the cursor to the target. Thus, MT is an interval from movement initiation until the cursor first enters a target. It means that MT began when RT ended. Therefore, MT represents the motor performance of the first movement execution phase.

Homing Time (HT): This indicates a combination of target acquisition and re-acquisition time. It simply measures the participants' capabilities of controlling the fine movements during the last phase of movement execution to complete each trial. Therefore, HT is the interval between first and final entry into the target area. In other words, HT begins when MT ends. During first entry, if the cursor was held inside the target area for 1 second, the value of HT was zero.

Directional error (DE): This occurs when the initial direction of the cursor movement is in the wrong direction that is more than 90 degrees away from a straight line to the target. For example, if the target is at 12:00 (positioned radially at the angle of 0 degree), and the movement is straight to the target or is within a "pie shape" which is 45 degrees to the left or right of the straight line (this would be 90 degrees total) then there is NO error. However if the movement is outside of this "pie shape" then the maximum degree of error will be the DE measurement. The values were converted to an absolute number expressed in degrees. In other words, DE indicates how much the direction of the initial cursor movement deviates from a straight path to the target. Therefore, DE measures the accuracy of the initial movement responses that are important to the performance of a directional SRC task.

Procedure

During the tests, participants were seated in an adjustable-height chair in front of a monitor approximately one meter away, and held a joystick that was mounted on the side of the chair. Participants were prevented from seeing movement of the joystick by an occluding screen while tasks were being performed. Participants were informed about the purpose and description of the task by written and oral explanations. They were not informed about the conditions under which they performed the task.

Participants moved the cursor immediately and kept it in the target for one-half of a second after the appearance of the target and an accompanying beep. The target turned blue when the participant successfully placed the cursor in the target. If the cursor was not held in the target long enough or passed through too quickly, then the target returned to its original color (red, green, yellow, or white depending on the condition). Targets were presented randomly on the monitor and were positioned radially at angles of 0, 45, 90, 135, 180, 225, 270, and 315 degrees. Customized software recorded the data from the joystick and monitor.

Upon completion of each trial, the target disappeared before the next trial began. Furthermore, if a participant started moving the cursor before the target was presented or did not have the joystick in a neutral position, an ‘anticipatory error’ message appeared on the screen and the trial was repeated. The target randomly appeared at one of eight positions on the computer screen and remained there until successful completion of the trial. When a participant completed the required task, the next trial followed after an inter-trial interval of 5-6 seconds. The computer changed the tasks from compatible to incompatible without manually rotating the joystick 180 degrees. Cursor movements and target positions were displayed on a computer controlled color monitor.

Each participant's assignment was functionally random with the first male and female participants being assigned to the first testing condition, the second male and female participants assigned to the second testing condition, and so on (i.e., no participant was deliberately assigned to a particular test condition). Assignments to each condition were based on having an equal number of male and female participants tested by the next scheduled testing day.

There were four experimental groups (conditions) with eight participants (four male, four female) per group and were exposed to two distinct tasks (compatible and incompatible) with two different control orders, position and velocity (see Figure 1). A total of 480 (3 phases of 160) test trials were performed for each condition. All four experimental conditions were comprised of three phases, each of which was distinguished by the color of the target (red, yellow, or green). Each phase included 160 trials (20 blocks of 8 trials). Participants were allowed 10-minute rest breaks between each test phase.

The first phase and the last phase, respectively, required performance of the same task, position control compatible (PC) and velocity control incompatible (VI) for all four groups. The interpolated task in the second phase, requiring another 160 trials, remained the same for group 1 (position compatible, PC), but was changed to position incompatible (PI) for group 2, to velocity compatible (VC) for group 3 and to velocity incompatible (VI) for group 4. This procedure yielded the following four experimental conditions:

PC-**PC**-VI**:** Participants continued to practice the first, position control compatible (PC) task during the second phase.

PC-**PI**-VI: Participants performed a position control incompatible (PI) task in the second phase between the PC and the velocity control incompatible (VI) tasks.

PC-**VC**-VI: A velocity control compatible (VC) task was interpolated between the PC and VI tasks.

PC-**VI**-VI: The interpolated task was the same as the velocity control incompatible (VI) task in the third phase.

Data Reduction and Analysis

The last 160 trials (retention tests) of each condition's total of 480 trials were imported into a statistical package program (SPSS) to calculate a mean, standard deviation, and standard error of the mean trial for each participant. These descriptive data were used to graphically characterize performance and adaptation. A general Multivariate Analysis of Variance (MANOVA) with repeated measures was conducted on each of the test measures by simultaneously determining the effects of between-participant and within-participant factors on the dependent variables. An independent-samples t-test was made for each hypothesis with an alpha level of $p<0.05$ selected to indicate significant differences.

The first analysis focused on the differences in the performance measurements excluding the testing conditions. The second analysis focused on whether testing conditions (sequential versus simultaneous practice) have different effects on male and female participants' performances for the retention (VI) task.

Results

Reaction Time

For the RT data, males (M=439 ms, SD=82 ms) were significantly faster than females (M=565 ms, SD = 125 ms), $t(31) = 3.33$, $p=0.0024$ (see Table 1). A significant main effect of gender was observed, $F(1, 36) = 15.98$, $p<0.001$, partial eta^2 = 0.363, power = 0.971. In addition, reliable interaction involving gender, control order (position vs. velocity) and compatibility (compatible vs. incompatible), $F(1, 36) = 8.82$, $p = 0.006$, partial $eta^2 = 0.240$, power = 0.818) was revealed.

Table 2 decomposes this interaction into all eight possible conditions, focusing on gender comparisons for the four experimental conditions (PC, PI, VC, and VI). These comparisons only revealed a reliable difference between males and females in the VC condition ($p = 0.005$). Although male participants were generally faster for RT, there was no statistically significant difference in RT for the VI task between the male and female participants of PC, PI and VI groups ($p > 0.05$) (See Table 2).

Movement Time

Overall, male participants were significantly faster for MT (M=865ms. SD= 161 ms. vs. 1280 ms, SD = 330 ms), $t(31) = 4.60$, $p = 0.0001$ (see Table 1). The MANOVA for the MT data uncovered significant main effects of gender, $F(1, 36) = 38.77$, $p < 0.001$, partial $eta^2 = .581$, power = 0.999, as well as compatibility (compatible vs. incompatible), $F(1, 36) = 4.81$, $p = 0.037$, partial $eta^2 = 0.146$, power = 0.562.

Several interactions were also observed. These included 2-way interactions between gender and compatibility (compatible vs. incompatible), $F(1,36) = 5.37$, $p = 0.028$, partial $eta^2 = 0.161$, power = 0.609, and between control order (position) versus compatibility and compatibility versus incompatibility $F(1,36) = 4.94$, $p = 0.043$, partial $eta^2 = 0.138$, power = 0.535, as well as a 3-way interaction between gender, position control order vs. incompatibility, and compatibility vs. incompatibility, $F(1,36) = 13.42$, $p < 0.001$, partial $eta^2 = 0.324$, power = 0.942. Table 2 contains the means for this 3-way interaction. Making gender comparisons across all four conditions, only a reliable difference between males and females in the VC condition ($p=0.001$) was present. There was no significant difference ($p>0.05$) in MT, for the VI task, between female and male participants of PC, PI and VI groups (see Table 2).

Homing Time

For the HT data, a significant main effect of gender was observed, $F(1, 36) = 9.84$, $p = 0.004$, partial $eta^2 = 0.260$, power = 0.857, with males (M=107.35 ms, SD=65.55 ms) being significantly faster than females (M=215.69 ms, SD = 148.47 ms), $t(31) = 2.32$, $p = 0.0279$ (see Table 1). A 3-way interaction involving gender, position vs. velocity control order and compatibility vs. incompatibility $F(1, 36) = 5.30$, $p = 0.029$, partial $eta^2 = 0.159$, power = 0.604) was also present in the data. This 3-way interaction is represented in Table 2, which focuses on gender comparisons for the four experimental conditions. Like the previous dependent measures, the only reliable difference was between males and females in the VC condition ($p = 0.054$).

Directional Error

For the DE data, the MANOVA revealed a significant main effect of gender, $F(1,36) = 20.64$, $p < 0.001$, partial $eta^2 = 0.424$, power = 0.992, with males (M = 14 degrees, SD = 5.90 degrees) demonstrating lower mean error rates compared to females (M = 29 degrees , SD = 16.32 degrees), $t(31)=3.62$, $p = 0.0011$, as well as a significant main effect of compatibility vs. incompatibility, $F(1,36) = 5.00$, $p = 0.033$, partial $eta^2 = 0.152$, power = 0.579, with lower error present in the incompatible trials (M=17.22 degrees, SD = 8.50 degrees) compared to the comp trials (M = 24.22 degrees, SD = 17.34 degrees) (see Tables 1 & 2). Finally, consistent with the other dependent measures, a 3-way interaction was observed involving gender, control order (position vs. velocity), and compatibility (compatible vs incompatible), $F(1, 36) = 6.44$, $p =$

0.017, partial eta^2= 0.187, power = 0.688. The means for this 3-way interaction are presented in Table 2. Focusing on gender differences, reliable differences between males and females were observed in the PI (p=0.055) and VC (p=0.064) conditions.

Discussion

A general Multivariate Analysis of Variance (MANOVA) with repeated measures and independent-samples t-test was conducted to test the hypothesis, under all the testing conditions in the four dependent variables. In this study male participants were faster and more accurate when performance is aggregated across conditions (see Table 1). There was a significant main effect of gender on the performance for all the dependent variables. However, when focusing on gender comparisons for the four experimental conditions (PC, PI, VC, and VI), the only reliable statistical difference was between males and females in the VC condition (see Tables 2).

The results of this study are consistent with previous findings (Blough, & Slavin, 1987; 1983; Schueneman, et al., 1985; Schiff, & Oldak, 1990) that male participants were significantly faster overall for RT, MT, HT and had lower error rates (DE) than females who performed more slowly and with a higher error rate than males (see Table 1). However, the testing conditions (context) significantly contributed to the performance inconsistencies in female participants as illustrated by the significant difference in performance among the female participants assigned to one of the four testing conditions (groups) (see Table 2.)

Table 2 shows that the performances of the females assigned to the VI (PC-VI-VI) group were comparable with those of the males of the same group. Female participants of the VI group performed significantly better than the females of the PC, PI and VC groups. There were no significant differences in RT MT, and DE between male and female participants of the VI experimental condition; females actually had faster HT than males in the VI test condition. Note that female participants assigned to VI group produced the best performances, which were not significantly different from that of the male participants, for the dependent measures in the third phase.

This is interpreted to be the result of the experimental task used in this study, which was closely associated with previously popular video games, many of which employed joysticks for control. It is presumed that, in the USA, young adult males have had more experience and have spent more time in playing video games, and receive greater freedom, encouragement and positive reinforcement to explore and participate in certain activities related to visual aiming, and target- acquisition tasks during early childhood than have females (Barnet et al, 2010; Subrahmanyam & Greenfield, 1994; Dorfberger, et al., 2009; Grantcharov, et al., 2003; Gur, et al., 2012; Hartmann & Klimmt, 2006; Kass, et al., 1998; Sanders, 2013; Schueneman, et al., 1985;Thorson, et al., 2011). (Blough, & Slavin, 1987; 1983; Schueneman, et al., 1985; Schiff, & Oldak, 1990).

It has been claimed that females dislike video and computer games because of their stereotyping of the characters (which is thought to be associated with sexual gender roles) competitive elements, violent contents, and their lack of meaningful social interactions (Hartmann & Klimmt, 2006). Additionally, Shinnar, et al. (2012) argued that because gender role, which shapes “gender typing of jobs”, women avoid certain tasks that are considered appropriate for the men. They (Shinnar, et al., 2012) discovered that “perceived lack of competency “is one of the significant gender related barriers for women. This barrier has a significant negative effect on women performance for certain occupations in the USA. Therefore, women are more prone the fear of failure and lack of competency that prevents them exploring and involving in learning certain skills or occupations usually dominated by men (Shinnar, et al., 2012).

The results clearly support the assumption that the context in which performance is measured is a significant contributing factor in the deterioration of female performances during adaptation to a complex visual motor task. While males of PC, PI and VC groups had overall better performance than females of the same groups, female performances under PC-VI-VI test conditions were similar to those of males and there were no significant performance differences in VI test conditions between genders (see Table 2).

The results of this study indicate that males and females exhibit similar strategies and movement behavior when the task is complex and unfamiliar such as the retention task, VI, in this experiment. When the participants switched from PC to VI task, the following modified movement behaviors were observed from both male and female participant' hand (joystick) and cursor movements: 1) hand (joystick) movements became more repetitive; 2) there were many small intermittent cursor movements on the screen; and 3) they moved the cursor first horizontally and then vertically toward diagonal targets, rather than straight, as in position control tasks. However, it must be noted that males adopted these movement patterns only when the two task factors (compatibility and control order) abruptly changed from position control compatible (PC) to velocity control incompatible (VI) after the several unsuccessful trials of the VI task. On the other hand, female participants used the preceding motor learning strategies even in relatively easier tasks such as PC, PI and VC and, most of the time, kept the same movement strategies much longer than male participants did, until they became more familiar with the changing task factors. In other words, females were more cautious – slower and making more intermittent joystick movements– while males were moving the cursor fast and straight to the target, which carried risks for overshooting (HT) and making more boundary and greater directional errors.

Therefore, practicing two task components simultaneously (whole practice) emerged to be more beneficial for women than practicing two task components sequentially (part practice) for velocity incompatible tasks (VI). This is because practicing each component unnecessarily extends the time of training. Therefore, practicing the two task components simultaneously may be a more correct progression for women to learn a complex directional SRC task.

Although this study also does not give direct evidence for socioeconomic causes for gender differences, it is very compatible with attributing gender differences in performing certain visual-spatial tasks to mainly socioeconomic and cultural influences. Cultural values and beliefs often reinforce the gender role that gives males advantages for mastering real-life tasks (Castel et al., 2005; Levine, et al., 2005; Shinnar, et al., 2012; Subrahmanyam & Greenfield, 1994). The results of this present study rather suggest that women should be given more freedom, encouragement and positive reinforcement to explore and participate in certain visual spatial tasks during early childhood. This is because many visual spatial tasks, like those used in this study, involving target-acquisition, visual aiming, and controlling an object's speed, position, and direction on a display are often under-practiced by women. Mastering these visual motor skills is important because these skills can be transferred to real life occupations, such as operating heavy machines, airplanes, drones, and medical surgery equipment that are often considered more appropriate for men.

This study implies that gender differences in performing visual motor tasks should not be exaggerated because they may carry a greater risk of promoting gender-based discrimination in the workplace (Hyde, 2005). However, we should not ignore differences just because the current social, cultural, and task contexts in real-life motor skills are advantageous to males and may discourage women from becoming involved in performing certain visual motor tasks.

Conclusion

In conclusion the current study with a limited sample size presents evidence that the current social, cultural, and task contexts, not the motor control and learning deficiencies affect women’s performance in complex visual motor tasks. The results showed that, although males’ performance appeared to be better overall (largely due to small differences accumulates)across conditions), women performed as well as men and even better for HT when practicing the altered task factors simultaneously in a complex visual motor task. Therefore, it may be concluded that gender differences in complex directional visual motor tasks are often task-specific with inter-individual variability.

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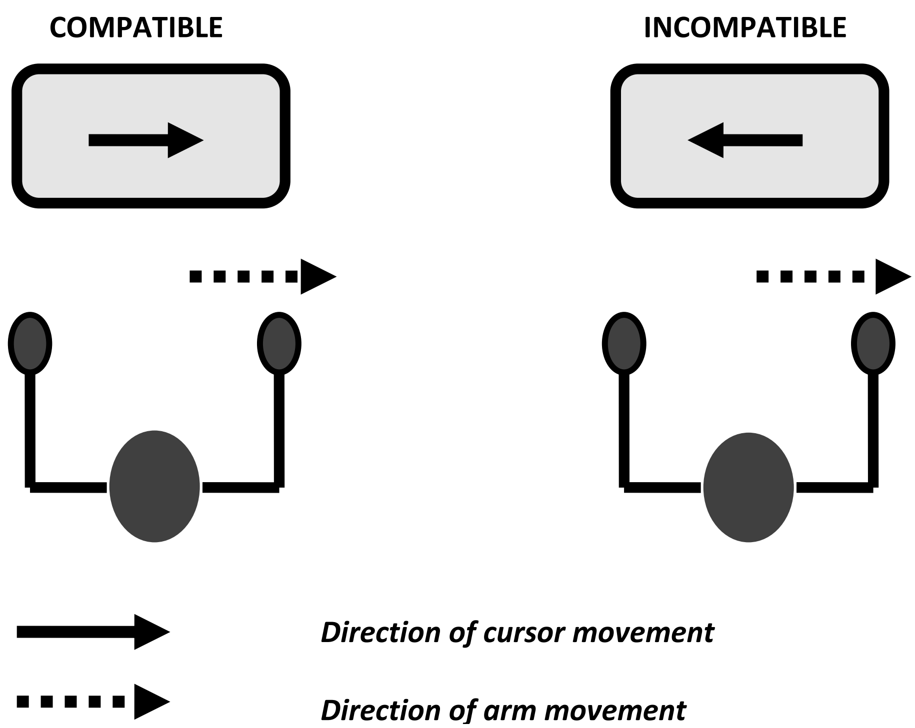

Figure 1. Compatible and incompatible, task.

The generic task was to guide the cursor onto the target as quickly as possible using hand movements on a joystick.

Table 1

Mean Performance Scores of Male and Female Participants

	Male		***Female***			
	M	**SD**	**M**	**SD**	**t**	**p**
RT	439	84.08	565	125.12	3.33	*0.006**
MT	865	161.36	1280	329.71	4.60	*0.0001**
HT	107	65.55	216	148.47	2.32	*0.004**
DE	14	5.90	29	16.32	3.62	*0.0011**

Note. Table represents mean (M) and standard deviation (SD) in milliseconds ms and degrees of male and female participants for Velocity Incompatible Task VI, excluding the testing conditions in, all four dependent variables; Reaction Time RT, Movement Time MT, Homing Time HT, and Directional Error DE.

** Differences are significant at $p < 0.05$.*

Table 2

Statistical Values of Dependent Variables for Each Test Condition

Reaction Time (RT)

	Females		**Males**						
Condition	**M** (ms)	**SD** (ms)	**M** (ms)	**SD** (ms)	**t**	**p**	**Cohen's d**	**effect-size r**	**power**
PC	519	102	470	73	0.79	0.429	0.542	0.262	0.125
PI	555	107	384	49	2.97	0.170	2.063	0.718	0.844
VC	690	97	425	86	4.28	*0.005**	2.891	0.822	0.999
VI	495	129	479	100	0.21	0.844	0.141	0.070	0.055

Movement Time (MT)

	Females		**Males**						
Condition	**M** (ms)	**SD** (ms)	**M** (ms)	**SD** (ms)	**t**	**p**	**Cohen's d**	**effect-size r**	**power**
PC	1218	227	910	205	2.11	0.079	1.423	0.580	0.559
PI	1303	376	816	151	2.44	0.093	1.701	0.648	0.684
VC	1643	143	810	133	8.95	*0.001**	6.030	0.949	0.999
VI	957	98	922	167	0.39	0.711	0.253	0.126	0.067

Homing Time (HT)

	Females		**Males**						
Condition	**M** (ms)	**SD** (ms)	**M** (ms)	**SD** (ms)	**t**	**p**	**Cohen's d**	**effect-size r**	**power**
PC	221	138	117	93	1.29	0.254	0.883	0.404	0.224
PI	306	202	110	36	1.91	0.152	1.349	0.559	0.482
VC	250	113	70	33	3.09	*0.054**	2.165	0.735	0.870
VI	86	52	132	81	-1.04	0.344	-0.679	-0.321	0.179

Directional Error (DE)

	Females		**Males**						
Condition	**M** (deg)	**SD** (deg)	**M** (deg)	**SD** (deg)	**t**	**p**	**Cohen's d**	**effect-size r**	**power**
PC	26	11	18	5	1.26	0.298	0.872	0.400	0.241
PI	23	9	9	3	3.06	*0.055**	2.142	0.731	0.863
VC	46	23	12	5	2.88	*0.064*	2.024	0.711	0.820
VI	23	9	17	6	1.15	0.304	0.782	0.364	0.208

Note. Table represents male and female participants' statistical values of 20 blocks, 160 trials, of VI task for each test conditions. *M= Mean (ms., deg.), SD= Standard Deviation.*

** Differences are significant at p < 0.05.*