EXPERIMENTAL INVESTIGATIONS

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Gender-Dependent Bimanual Task Performance

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Key words: *reaction time; response accuracy; movement velocity; bimanual response; gender.*

Summary. *Background and Objective. Many studies have suggested that each hand has a different special talent; however, there is a lack of data in the area of goal-directed bimanual hand coordination and its dependence on gender. The aim of this paper was to investigate gender-dependent bimanual speed-accuracy task performance.*

Material and Methods. Twelve healthy young males and twelve healthy young females (all right-handed) performed protractile movements with both arms simultaneously by pushing joysticks toward two targets as quickly and accurately as possible.

Results. Though no significant difference was observed in the reaction time during a unimanual speed-accuracy task between the left and right hands as well as men and women, during a bimanual task, the reaction time of both the hands was significantly longer in women than men. There was no significant difference in the velocity of both the hands during a bimanual speed-accuracy task between men and women, while the accuracy of the left hand was significantly greater in men than women. There was no significant difference in intraindividual variability in the reaction time, maximal velocity, and path of movement between men and women as well as the left and right hands, but variability in the average velocity of the right hand both in women and men was significantly greater compared with their left hand.

Conclusions. Whereas people typically look at the target location for a reaching movement, it is possible that two objects are simultaneously fixated.

Introduction

According to traditional views, the right hemisphere is more involved in spatial activities (e.g., producing smaller movement errors) (1), whereas the left hemisphere is more involved in temporal activities (2). The left hand (nondominant) is specialized for movement preparation and the visuospatial aspects of movement evidenced by shorter reaction time (RT) to localize targets (3). The right hand (dominant) has a specialized role in the coordinated timing of pointing actions and more effective use of limb dynamics through intersegmental coordination of reaching movement (4). Unimanual aiming movements have been reported to be planned faster and controlled more accurately for the left (or nonpreferred) hand than for the right (or preferred) hand (5, 6). Thus, the RT of the left hand was shorter and the accuracy was better than that of the right hand, but the right hand performed the movement faster.

It has been established that the principles of bimanual movement cannot simply be extrapolated from the laws of single-limb movement (7–10, 11).

There are numerous studies analyzing reaction time, movement speed and accuracy, and their dependence on gender (12–15) and the right or left hands (12, 13, 16). It is traditionally accepted that the female human brain is less lateralized than that of males (12). Males have been reported to have faster reaction times than females, and this drawback is not reduced by training practice (15). However, in the speed-accuracy task, women performed more slowly and accurately than men (13, 14). Despite these and other findings, it is still not clear what main differences exist between men and women performing bimanual task.

Although many studies have suggested that each hand has a different special talent, there is, however, a lack of studies in the area of goal-directed bimanual hand coordination and its dependence on gender. Besides, it has been determined that intraindividual variability of reaction time is a significant criterion of cognitive performance capacity (17–20). However, we have not found any data about the differences in intraindividual variability of reaction time, move-

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ment speed and accuracy during speed-accuracy tasks between male and female subjects as well as between the left and right hands performing bimanual tasks.

In this study, the following research questions were intended to answers: a) if the left hand reacts faster performing speed-accuracy unimanual task (3, 5), does the same law work performing bimanual task? b) if women perform speed-accuracy unimanual task more accurately but slower than men, and their reaction time is shorter (13–15), does the same law work in the performance of bimanual task? c) do both hands work synchronically performing bimanual task? and d) are the intraindividual variability of reaction time as well as kinematic characteristic of movement of the left hand of right-handed people greater than those of the right hand performing a bimanual task? The aim of this study was to investigate dominant and nondominant hand differences in interjoint coordination during targeted rapid aiming bimanual movements. The performance of the dominant and nondominant hands during rapid aimed bimanual reaching task (50 repetitions) in 12 adult neurologically intact, right-handed men and 12 women was compared.

Material and Methods

Subjects. Twelve healthy men with a mean age of 20.8 years [SD, 1.1] (body weight, 77.0 kg [9.2]; height, 182.33 cm [6.65]) and 12 healthy women with a mean age of 21.4 years [SD, 1.2] (body weight, 61.1 kg [6.2]; height, 170.3 cm [4.7]) were enrolled into the study. All the subjects were right-handed. The assessment and analysis of handedness was performed by the Edinburgh Inventory (21). The subjects were informed about the course of the study. All of them were physically active, but they did not take part in any formal physical exercise or sports program.

Methods. All the experiments took place from 9 AM to noon. The subjects had no physical load before the experiments. The subjects were asked to perform two tasks: a) a simple reaction task with one hand (10 repetitions with the right and left hands); and b) a triple task with the right and left hands simultaneously: react as fast as possible and move to two targets with maximal speed and maximal accuracy with both hands (bimanual symmetrical speed-accuracy task toward separate visual targets) (50 repetitions with each hand were performed). The movements were performed in the natural reaching space in an upward-forward direction, involving shoulder and elbow movements. The interval between repetitions in both tasks was 2–5 s (the interval between the tasks performed by different hands and one or both hands was 1 min). The hands were chosen randomly. Two-three days before the experiment, the subjects were introduced to both tasks (they tried to perform each task about 10–15 times).

During the study, the subjects were seated in a special chair at the table with a DPA-1 (Fig. 1) fastened to it (22). The subject's back was straight and leant at the backrest; both arms were bent 90° at the elbow joint so that the upper arms were nestled against the sides, and the forearms rested on the DPA-1 support panel. The distance between the hands at the start place as well as the target was 20 cm. The position of DPA-1 chair was regulated so that the subject could sit comfortably and take a standard position. The distance between the computer screen and the subject's eyes was approximately 70 cm. The participant's right and left hands were fixed to joysticks, from which the path and velocity of hand movements at the distal part of the hands were recorded. The sampling rate was 100 Hz. The handle at the end of the lever was adjusted to accommodate the participant's hand (the lever was allowed to move only in a horizontal plane). For each experiment, the reaction time (time to movement initiation from the start of motion stimulus) was measured.

The target appeared in the same place on the screen (the distance from the start zone to the target was 0.17 m) (Fig. 2). The subjects were instruct-

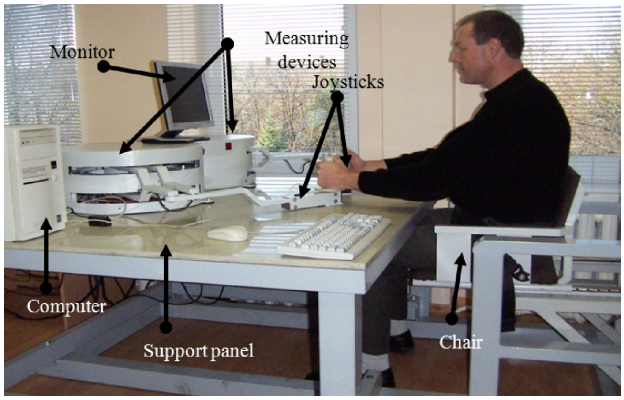

Fig. 1. The analyzer of dynamic parameters of human leg and arm motion DPA-1

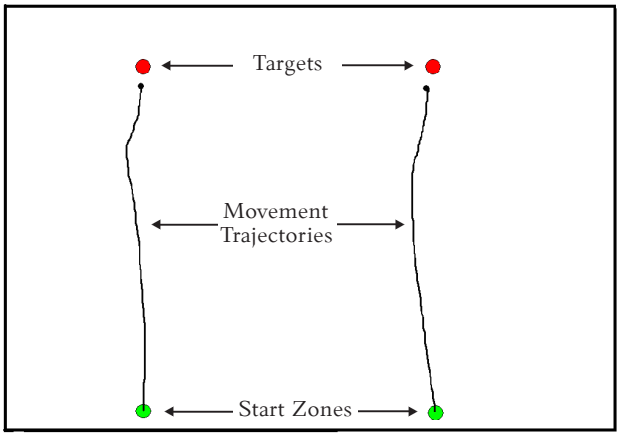

Fig. 2. The view of movements performed on the monitor

ed to focus on the cross in the center of the screen, react as fast as possible to the auditory and visual signal (appearance of circle 0.7 cm in radius on the screen), and push the joystick with their hand as fast as possible and with the greatest accuracy to the target and then to stop the movement. The endpoint of the movement was recorded when the center of the handle symbol stopped in the circle and stayed there for no less than 0.02 s. During each task, the subject was required to position the handle symbol 0.35 cm in radius in the start zone (the center of circle 0.1 cm in radius) on the computer screen. The program intermittently generated a sound signal and a target on the computer screen, and the subject had to react to it by pushing the handle. The measurement cycle was completed after hitting the target with the circle of the handle symbol.

On the days of the experiment, after the task was explained to the subjects, they were allowed 5 practice attempts, the results of which were not recorded. The results of each repetition were shown to the subjects on the computer screen, and they were verbally instructed to do their best. The average reaction times (simple reaction time, RTs, and complex reaction time, RTc, in the first and second tasks respectively) were calculated. In the second task, the average velocity (Va), maximal velocity (Vm), time to Vm (Tv), and path of movement (S) from 50 repetitions were also calculated. Besides, the intraindividual variability (coefficient of variation, CV) of these variables was calculated.

Statistical Analysis. The two-way analysis of variance (ANOVA) for repeated measures was used to determine the effect of gender (female vs. male) and lateralization (right vs. left hand) on different measurements. If significant effects were found, post hoc testing was performed applying paired *t* tests with a Bonferroni correction for multiple comparisons. Descriptive data are presented as means (SD). The level of significance was set at 0.05. Based on alpha level of 0.05, the sample size (n=12), standard deviations, and the average level of variables, statistical power (SP) was calculated for all mechanical indicators. In order to evaluate the relationship between the right and left hands in different variables, the Pearson coefficient of correlation was calculated.

Results

No significant difference ($P>0.05$) was found in RTs between women and men as well as between the right and left hands when performing the unimanual task (Fig. 3). However, during the bimanual task, the RTc of both the right and left hands was significantly shorter in men than women ($P<0.05$) (Fig. 4). There was no significant difference in the Va and Vm between women and men (Figs. 5 and 6). No significant difference ($P>0.05$) was observed in the Va and Vm between the right and left hands in women; however, in men, the Va and Vm of the right hand were significantly greater ($P<0.05$) as compared with those of the left hand (Figs. 5 and 6). The Tv (time to maximal velocity of movement) of the right hand was shorter than that of the left hand both in women and men; however, there was no significant difference in the Tv between women and men (Fig. 7). Moreover, no significant difference in the S between the right and left hands was found ($P>0.05$); however, the S of the left hand in men was shorter than that in women (Fig. 8).

No significant differences in intraindividual variability (CV) of RTc, Vm, and S between women and men as well as between the right and left hands were found ($P>0.05$) (Fig. 9). However, the CV of Va both in women and men as well as the right and left hands was significantly greater than other indices ($P<0.05$). Besides, the CV of the Va of the right hand was greater than that of the left hand ($P<0.05$). The CV of S in men and women was significantly smaller than CV of Vm, Va, and RTc.

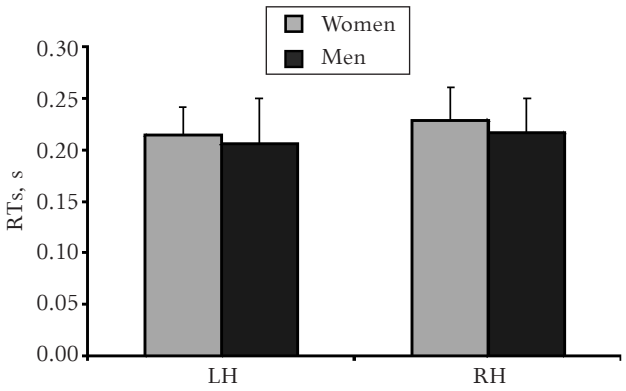

Fig. 3. The mean values of simple reaction time (RTs) in women and men performing a unimanual reaction time task with 10 repetitions

LH, left hand; RH, right hand.

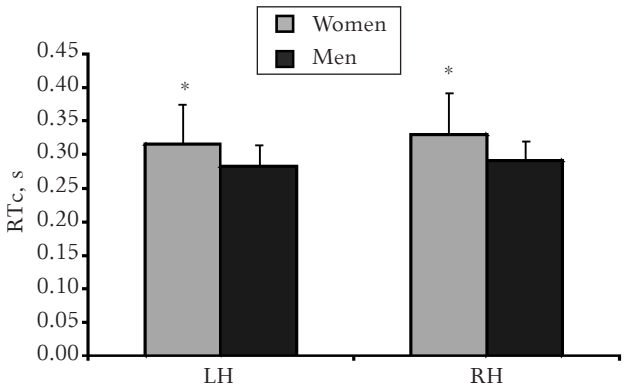

Fig. 4. The mean values of reaction time (RTc) in women and men performing a bimanual speed-accuracy task with 50 repetitions

LH, left hand; RH, right hand.

*$P<0.05$, women compared with men.

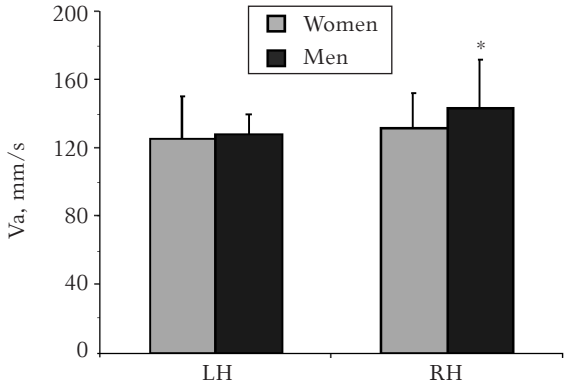

Fig. 5. The mean values of average velocity of movement (Va) in women and men performing a bimanual speed-accuracy task with 50 repetitions

LH, left hand; RH, right hand.
*$P<0.05$, between LH and RH.

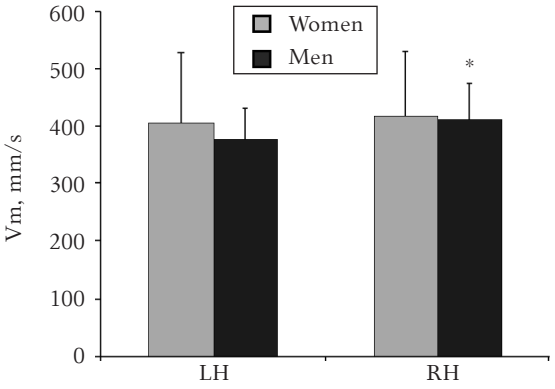

Fig. 6. The mean values of maximal velocity of movement (Vm) in women and men performing a bimanual speed-accuracy task with 50 repetitions

LH, left hand; RH, right hand.
*$P<0.05$, between LH and RH.

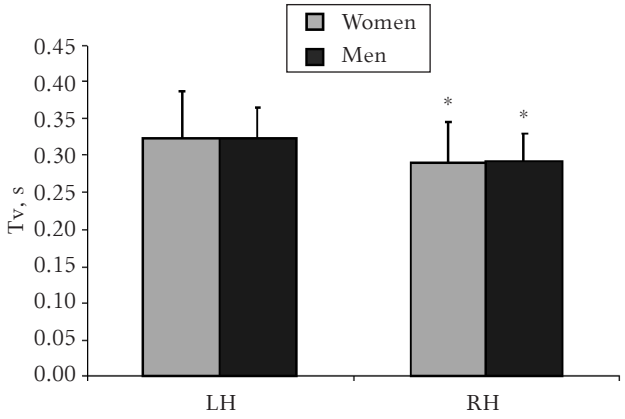

Fig. 7. The mean values of time to maximal velocity of movement (Tv) in women and men performing a bimanual speed-accuracy task with 50 repetitions

LH, left hand; RH, right hand.
*$P<0.05$, between LH and RH.

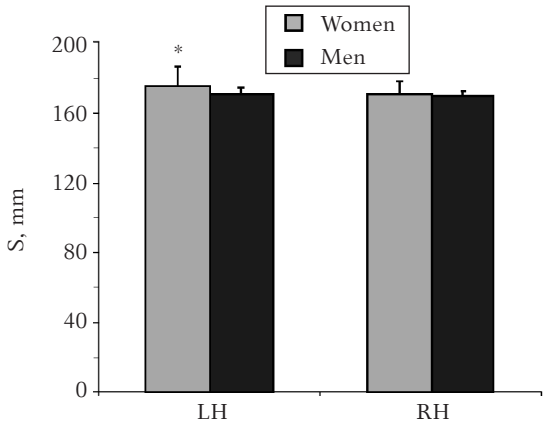

Fig. 8. The mean values of path of movement (S) in women and men performing a bimanual speed-accuracy task with 50 repetitions

LH, left hand; RH, right hand.
*$P<0.05$, women compared with men.

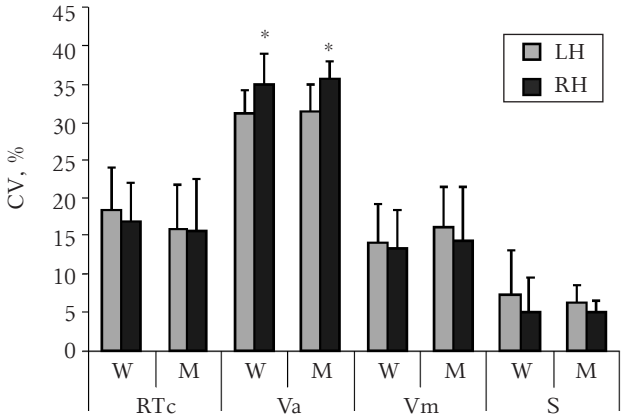

Fig. 9. The coefficient of variation (CV) of reaction time (RTc), average velocity (Va), maximal velocity (Vm) and path of movement (S) in the right (RH) and left hands (LH) during a bimanual speed-accuracy task

*$P<0.05$, between LH and RH.

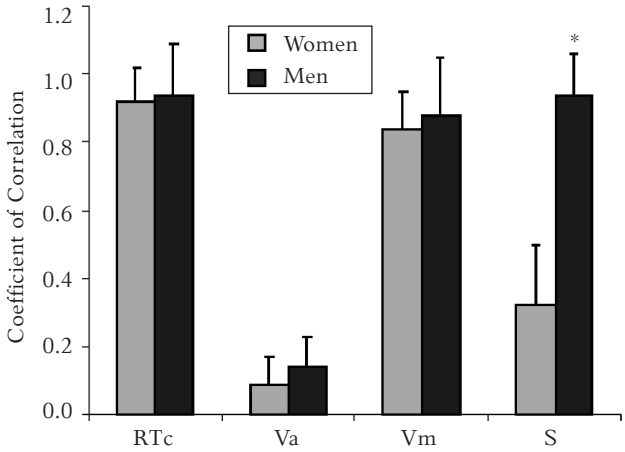

Fig. 10. The cross correlation coefficient between the left and right hands during a bimanual speed-accuracy task with 50 repetitions

*$P<0.05$, men compared with women.

A significant intraindividual cross-correlation of RTc and Vm between the right and left hands both in men and women was determined ($P<0.05$); however, there was no significant difference between men and women (Fig. 10). Besides, intraindividual cross-correlation of S between the right and left hands was significantly greater in men than women ($P<0.001$).

Discussion

The first finding of our study is that there was no significant difference in the reaction time during a unimanual speed-accuracy task between the left and right hands and between men and women. This contradicts to the findings of Carson et al. (3) and Boulinquez and Bartélémy (5). These authors reported that the left hand reacted faster performing a unimanual speed-accuracy task. Moreover, Der and Deary established that the reaction time in men was shorter than in women (15).

The second finding of our study is that during a bimanual task, the reaction time of both hands was significantly longer in women than men. It has been recently concluded that the two hands have different internal models and specialties: closed-loop control for the right hand and open-loop control for the left hand (11). Consequently, it was suggested that during bimanual movements, both models might be used creating better control and planning, but requiring more computation time compared to the use of one hand only. This is in accord with our data showing that RTc was significantly longer than RTs. However, it is rather strange why the RTc in women was longer than men as there was no significant difference in the RTs between men and women.

The third finding of our study is that there was no significant difference in the velocity during a bimanual speed-accuracy task between men and women as well as the left and right hands, while the accuracy of the left hand was significantly greater in men than women. It is contrary to the data that women's reaction time is longer and speed of movement is slower, whereas their accuracy of movement is better compared to that of men performing a speed-accuracy unimanual task (13–15, 23). However, women accomplished the Moberg Pick-Up Test (i.e., test for assessing hand dexterity) faster than men did, and their task performance with the dominant hand was faster than that with the nondominant hand (24). Thus, the principles of bimanual movement cannot be simply extrapolated from the laws of single-limb movement (7–11). Our findings showed that the Tv of the right hand was significantly shorter compared with the left hand in women as well as in men. Thus, their right hand movement was more ballistic than that of the left hand. It has been found that women often adopt a more feedback-based strategy to limb control, while men are more likely to rely on feed-forward processes to optimize speed and accuracy (25). This is the main reason why women perform movements more accurately but slower.

The fourth finding is that there was no significant difference in intraindividual variability (CV) in the RTc, Vm, and S between men and women as well as between the left and right hands, but variability in the Va of the right hand both in women and men was significantly greater compared to that of the left hand. It is well established that intraindividual variability in the reaction time is a reliable criterion of motor planning capacity (17–20). Accuracy and speed of the nondominant hand have been found to decrease more than those of the dominant hand when the complexity of movement performance increases (26). We expected that right-handed people would have more difficulties in controlling their movements with the left hand, and thus we believed that variability in the movement performance parameters of the left hand would be greater that that of the right hand. Other studies reported that men performed a speed-accuracy task more quickly and regularly than women (27). However, no difference in performance variability was found comparing men and women in our study.

The fifth finding of study is that the RTc and Vm between the left and right hands during a bimanual speed-accuracy task were more consistent than the Va. It may be assumed that control of motor planning variables (RTc) as well as Vm is more synchronized than the Va. Moreover, it was rather strange that the control of accuracy between the right and left hands was synchronized only in men. Researchers have found that both the hands were well synchronized at the goal with a high intermanual correlation in reaching the goal (28, 29). Thus, it has been concluded that there is an asymmetry in the feedback requirements of the two hand systems when accuracy is critical (10). Although according to the prevailing viewpoint bimanual coordination is assigned to a single brain locus, more recent evidence points to a distributed network that governs the processes of neural synchronization and desynchronization that underlie the rich variety of coordinated functions (30).

One limitation, however, is specific to bimanual reaching: whereas people typically look at the target location for a reaching movement, it is possible that two objects are simultaneously fixated.

Conclusions

Though there was no significant difference in the reaction time during a unimanual speed-accuracy task between the left and right hands as well as men and women, during a bimanual task, the reaction

time of both the hands was significantly longer in women than men. Besides, there was no significant difference in the velocity of both the hands during a bimanual speed-accuracy task between men and women, while the accuracy of the left hand was significantly greater in men than women. There was no significant difference in intraindividual variability (CV) in the RTc, Vm, and S between men and women as well as between the left and right hands, but variability in the Va of the right hand in both women and men was significantly greater compared to that of the left hand. The RTc and Vm between the left and right hands during a bimanual speed-accuracy task were more consistent than the Va. This methodology of movement studies can be successfully applied while testing motor function in neurological patients.

Statement of Conflicts of Interest
The authors have no conflicts of interest.

Veiksmo atlikimas abiem rankomis priklausomai nuo lyties

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Raktažodžiai: reakcijos laikas, atsako tikslumas, judesio greitis, reakcija atliekant judesį abiem rankom vienu metu, lytis.

Santrauka. *Tyrimo tikslas.* Daugelio tyrimų duomenimis, kiekviena ranka turi savų ypatingų gebėjimų, tačiau trūksta duomenų apie tikslingą abiejų rankų darbo koordinaciją ir jos priklausomybę nuo asmens lyties. Šio tyrimo tikslas – ištirti, kaip žmogaus atliekamas greitumo ir tikslumo reikalaujantis veiksmas priklauso nuo jo lyties.

Tirtųjų kontingentas ir tyrimo metodai. 12 jaunų vyrų ir 12 jaunų moterų (visi dešiniarankiai) atliko tiesiamuosius judesius abiem rankomis tuo pačiu metu, stumdami rankenėlę į du taikinius taip greitai ir taip tiksliai, kaip tik gali.

Rezultatai. Neradome statistiškai reikšmingų reakcijos laiko skirtumų, kai tiriamieji atliko greitumo ir tikslumo reikalaujantį veiksmą abiem rankomis atskirai, tačiau, atliekant veiksmą abiem rankomis tuo pačiu metu, moterų reakcijos laikas buvo reikšmingai ilgesnis nei vyrų. Nepastebėjome reikšmingų vyrų ir moterų greičio skirtumų atliekant veiksmą abiem rankomis tuo pačiu metu, bet vyrų kairės rankos tikslumas buvo didesnis nei moterų. Nenustatyta reikšmingų skirtumų tarp vyrų ir moterų reakcijos laiko, maksimalaus greičio ir judesio trajektorijos kitimo, taip pat tarp dešinės ir kairės rankos keitimo, tačiau vyrų ir moterų vidutinio greičio kitimas, atliekant judesius dešine ranka, buvo statistiškai reikšmingai didesnis nei atliekant juos kaire ranka.

Išvada. Kadangi, atlikdami siekimo judesį, žmonės paprastai žiūri į taikinį, todėl įmanoma tuo pačiu metu įsidėmėti du objektus.

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