

## **Gender Differences in Behaviourally Fractionated Omitted Stimulus Reaction Time Task using Visual, Auditory and Somatosensory Stimuli**

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### **ABSTRACT**

Although most studies in the field agree on gender differences regarding reaction times, disagreements also remain about this trend. This is a replication study with a large sample size designed to verify the consistency of a prior result that showed an absence of gender differences in omitted stimulus reaction time (OSRT) task using behavioural criteria to fractionate reaction time into Premotor (cognitive) and Motor components. A total of 112 healthy participants (56 males) responded to the termination of a train of visual, auditory, or somatosensory stimuli. The results did not support the previous finding and showed that men have faster Premotor and Motor responses on each of the three sensory modalities. Faster responses were obtained with auditory rather than visual or somatosensory stimuli. These results are relevant to developing a better understanding of the different time processing capabilities of the male and female brains.

*Keywords:* Cognitive, movement, multisensory, omitted stimulus, reaction time

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### **INTRODUCTION**

Time estimation is considered an important control mechanism in the behaviour of organisms and is an indirect index of the processing capabilities of the brain. It helps in determining sensory-motor associations and the alertness of a person because how quickly a person responds to a stimulus

depends on his/her reaction time (RT). A number of papers have found significant differences between men and women in distinct time estimation tasks (Bell, 1972; Delay & Richardson, 1981; Eisler & Eisler, 1992; Hancock, Vercruyssen, & Rodenberg, 1992; Rammsayer & Lustnauer, 1989). Others report no gender differences (Ayala, De Ste Croix, Sainz de Baranda, & Santonja, 2014; Hong et al., 2014; Marmaras, Vassilakis, & Dounias, 1995; Roeckelein, 1972; Teleb & Al Awamleh, 2012). One way to assess the time estimation is through the measurement of RT to sensory stimuli, which is considered to reflect the sum of the duration of a series of mental and motor processes, requiring stimulus perception, cognitive selection, and response execution (Welford, 1952). Much research has been published about RT, and it is clear that RT is influenced by several factors, such as age, practice, and drugs (Kosinski, 2013). Although gender differences in RT have been demonstrated in several studies (Adam et al., 1999; Dane & Erzurumluoglu, 2003; Der & Deary, 2006; Landauer, Armstrong, & Digwood, 1980; Riccio, Reynolds, & Lowe, 2001; Sherman, 1978), it is still a controversial issue (Teleb & Al Awamleh, 2012). Some authors have argued that males have faster RT than females (Barral & Debu, 2004; Dane & Erzurumluoglu, 2003; Der & Deary, 2006), even in animals (Bayless, Darling, Stout, & Daniel, 2012). Others suggest that the speed of response is a function of the type of stimuli presented (Burnstain, Bank, & Jarvick, 1980) and men have an advantage over women when

spatial or visual stimulus is presented, but women are faster when they must react to an auditory signal (Lahtela, Niemi, & Kuusela, 1985). Nevertheless, Spierer, Petersen, Duffy, Corcoran and Rawls-Martin (2010) found faster responses in men than women presented with auditory signals. Still other studies have found no gender differences in RT tasks (Teleb & Al Awamleh, 2012).

A different type of RT occurs when a task presents a recurring stimulus that requires an immediate response to the omission of the stimulus. This is known as an omitted stimulus reaction time (OSRT) task. Although the OSRT paradigm is somewhat uncommon, it bears a resemblance to some real-life situations such as those requiring reaction to the cessation of a flashing stoplight, or to a missing beep on a heart monitor. It is considered additional cognitive processes, such as sustained attention and mental chronometry to determine when the next stimulus is expected and discrimination of the cessation of a temporal stimulus sequence, that are not involved in choice RT tasks (Hernández, Huchin-Ramirez, & Vogel-Sprott, 2005; Bullock, Karamürsel, Achimowicz, McClune, & Başar-Eroglu, 1994). Most importantly, the trigger for the behavioural response is an internal cognitive process and not an external event. This task is also of considerable interest because the omitted stimulus potential (OSP), a special form of event-related potentials (ERPs), accompanies the cessation of a train of stimuli that lasts a few seconds (Bullock et al., 1994). Previous research has shown that the OSP and the OSRT share some qualities

(Hernández & Vogel-Sprott, 2008, 2009, 2010).

Research has shown that the total RT can be partitioned into Premotor (cognitive) and Motor (movement) components to determine the source of the timing delay related to a process (Botwinick & Thompson, 1966a). This procedure of fractionating RT to the presentation of a stimulus has been applied to simple and choice reaction time tasks (Botwinick & Thompson, 1966a; Ito, 1997; Raynor, 1998; Simmons, Wass, Thomas, & Riley, 2002) and also to the OSRT task, using behavioural fractionation (Hernández, et al., 2005).

Gender differences in the Premotor and Motor components of RT are also controversial. Botwinick and Thompson (1966b) found that these two components do not differ among men and women. Conversely, Ervilha, Fernandes Da Silva, Correa Araujo, Mochizuki and Hamill (2014) found faster Premotor fraction RT for athletic women, but faster Motor RT for athletic males, with no gender differences in the total RT. Hong et al. (2014) reported Motor fraction to be longer in elderly women but not in elderly men, with no gender differences in the Premotor component.

The only study of OSRT comparing the two fractionated measures in men and women was published by Hernández et al. (2005), in which a paradigm of lateralised stimuli and responses was used. In that report, analysis of variance (ANOVA) showed that men were faster than women

in the Premotor time, but this difference did not reach any significance. Although this was a statistically non-significant result, the observed male advantage motivated the researchers to conduct a further study to ascertain possible gender differences in the OSRT task in order to ratify or rectify such results. In this study, the number of males and females was more than twice those previously reported, and used only their dominant hand in responses with no lateralised stimuli. Gender differences in the OSRT are important because they show that the brain works differently in men and women to handle internal information such as the timing and expectation. Gender differences in the OSRT are particularly important to drug studies. Some cognitive information about the effects of acute doses of alcohol on the Premotor and Motor fractions of the OSRT in men has already been published, but the equivalent information in women is missing (Hernández, Vogel-Sprott, Huchín-Ramirez, & Aké-Estrada, 2006).

This study is an extension of a previous work on behaviourally fractionated RT to an omitted stimulus with the aim to verify the lack of gender differences previously reported. The main objective is to determine if gender influence exists in college students' responses to visual, auditory, and somatosensory stimuli in omitted stimulus reaction time (OSRT) task using behavioural criteria to fractionate reaction time into Premotor (cognitive) and Motor components.

## **METHODS**

### **Participants**

A total of 112 healthy college students volunteered for the study, 56 of whom were females with regular menstrual cycles. Although the cyclic hormones have no influence on the OSRT (Hernández, García-Martínez, Monteón, & Alfonso-Arguello, 2013), they were asked to arrive at the lab when they were in days 1-5 of the menstrual cycle. Right-handedness was assessed and confirmed using the Annett (1970), and Shimizu and Endo (1983) tests. All the participants were aged between 17 and 26 years (mean of  $20.4 \pm 2.1$  years), and none reported having any history of nervous system diseases or motor disability. Subjects with well-defined premenstrual syndrome, any gynaecological problems, irregular cycles, or any drug consumption (such as hormonal treatment and psychotropic drugs) were excluded from the study. The subjects were instructed to abstain from consumption of any stimulant drink or alcohol for at least 24 hours before their arrival at the lab. All the participants were informed of the procedures before completing an informed consent form and reported their age and health history. The protocol was reviewed and approved by the Ethics Committee of the university.

### **Apparatus and Materials**

This task was similar to that used in prior research to test the Premotor and Motor

RT to visual, auditory, and somatosensory stimuli (Hernández et al., 2005). A pattern generator (Grass mod. 10VPG) presented the visual stimuli on a monitor. The monitor presented a black and white checkerboard with 16 squares ( $5 \times 8$  cm each). The centre of the monitor was placed 30 cm in front of the participant's eyes. The generator, hidden from the participant's view was triggered and stopped by an electrical stimulator (Grass S48), which released a pulse every two seconds (0.5 Hz) that reversed the black and white squares. The electrical stimulator also triggered the auditory stimuli, which were presented as 10 ms 'clicks' at 2-second intervals to both ears through headphones. The auditory thresholds were determined by reducing the output voltage to a minimum and gradually increasing the voltage until the person detected the clicks. The stimulus pulse was then set at 20 times the threshold so that they would be clearly heard. The somatosensory stimuli were also administered at 2-second intervals by two disc electrodes (Grass F-E5SH) placed on the medial finger of the right hand. These electrodes were connected to the electrical stimulator (Grass S48) through a stimulus isolation unit (Grass SIU5). Somatosensory thresholds were also determined and set at 1.2-times the threshold, which was well below the pain threshold.

The responses to the termination of a train of stimuli in each sensory modality were measured. At the outset of the trial, a response key (Key 1) was depressed

with the thumb until the train of stimuli ceased. At this time, Key 1 was released and Key 2, placed 10 cm in front of Key 1, was depressed. Key 2 was large enough to avoid sacrificing speed for accuracy. Both response keys were connected to AC amplifiers (Grass P511). Each stimulus and the release and the press of the response keys generated clear changes in the voltage relative to the baseline that were collected online using a computer fitted with an analogue-to-digital converter (Biopac, Inc.) and analysed using AcqKnowledge software (Biopac Inc.). The computer recorded the time (in milliseconds) between the changes in voltage associated with each stimulus in the train of stimuli and the Key 1 and 2 responses. Premotor time (PM) was measured as the time between the first missing stimulus and the release of Key 1. Motor time (M) was measured between the release of Key 1 and the pressing of Key 2. A participant's PM and M were recorded for each trial, and separately for each sensory stimulus (visual, auditory or somatosensory) in the omitted stimulus task.

### Experimental Procedures

The participant was seated in front of a table where the two response keys were in easy reach. The task instructions were identical for each sensory modality. Participants were told to hold down Key 1 at the beginning of each trial and immediately release the Key 1 and press Key 2 when the train of stimuli

ceased. Each trial was preceded by a verbal 'ready' signal. The number of stimuli in a train on a given trial varied between five and 10 in a predetermined pseudorandom fashion and was ignored by the participants. A test included 30 trials, with 10 consecutive trials administered with each type of stimulus. Trials with a given stimulus were completed in approximately 10 minutes and were immediately followed by trials with a different sensory stimulus. The order in which the sensory stimuli (visual, auditory or somatosensory) were presented during the test was counterbalanced in the groups. A test with all three sensory stimuli was completed in approximately 30 minutes. The administration of additional trials would extend the duration of a test and possibly result in restlessness and fatigue effects.

### Data Analyses

The scores of any trial in which the response occurred before or coincided with the first missing stimulus in a train were discarded. In total, 0.8% of the trial scores were rejected. On each test, a participant's PM and M times were averaged using the trials with each sensory stimulus. SPSS software (SPSS, v.18) was used to analyse the OSRT measures using a 2 (gender, that is, men and women)  $\times$  3 (sensory, that is, visual, auditory, and somatosensory) ANOVA. A partial Eta-square value ( $\eta_p^2$ ) provided the ANOVA effect size. To correct the chance occurrence of a result with  $p < .05$

for repeated tests, a Bonferroni correction was used to adjust the alpha level. The assumptions of normality and equal variance were tested by the Kolmogorov Smirnov test and the Levene test, respectively.

**RESULTS**

The average age of the men was  $20.1 \pm 1.9$  years and was  $20.8 \pm 2.2$  for women, with no significant difference ( $p > .66$ ). A 2 (Gender)  $\times$  3 (Sense) repeated measures analysis of variance (ANOVA) for the Premotor OSRT yielded main effects on Gender ( $F(1,110) = 10.2, p < .002; \eta_p^2 = .085$ ) and Sense ( $F(2,220) = 38.5, p < .0001; \eta_p^2 = .259$ ), but not in their interaction ( $F(2,220) = .027; p > .584; \eta_p^2 = .005$ ). In the same way, the 2 (Gender)  $\times$  3 (Sense) ANOVA for the Motor OSRT yielded main effects on Gender

( $F(1,110) = 11.3, p < .001; \eta_p^2 = .093$ ) and Sense ( $F(2,220) = 9.87, p < .0001; \eta_p^2 = .082$ ), but not in their interaction ( $F(2,220) = 1.376; p > .255; \eta_p^2 = .012$ ). Comparisons with Bonferroni test indicated that the auditory modality was faster than the visual and somatosensory modalities ( $p < .0001$ ), and the visual modality was faster than the somatosensory modality ( $p < .002$ ) in the Premotor component (Table 1). The Motor component did not have any main differences between the visual and auditory systems, but these were both faster than the somatosensory modality ( $p < .002$ ) (Table 1). Separate paired t-tests for each stimulus modality verified that the men’s responses were faster than the women’s responses in both the Premotor ( $p < .011$ ) and Motor ( $p < .021$ ) fractions of the OSRT (Figure 1).

Table 1  
*Comparison of the Premotor and Motor times in the sensory modalities for the sample*

Times	Sensory Modality		
	Auditory	Visual	Somatosensory
Premotor (ms)	665.1 $\pm$ 237.7*	809.4 $\pm$ 304.4	915.1 $\pm$ 360.6
Motor (ms)	506.8 $\pm$ 166.8	501.9 $\pm$ 158.1	553.6 $\pm$ 181.1**

\* $p < .0001$  compared to visual and somatosensory

\*\* $p < .002$  compared to auditory and visual

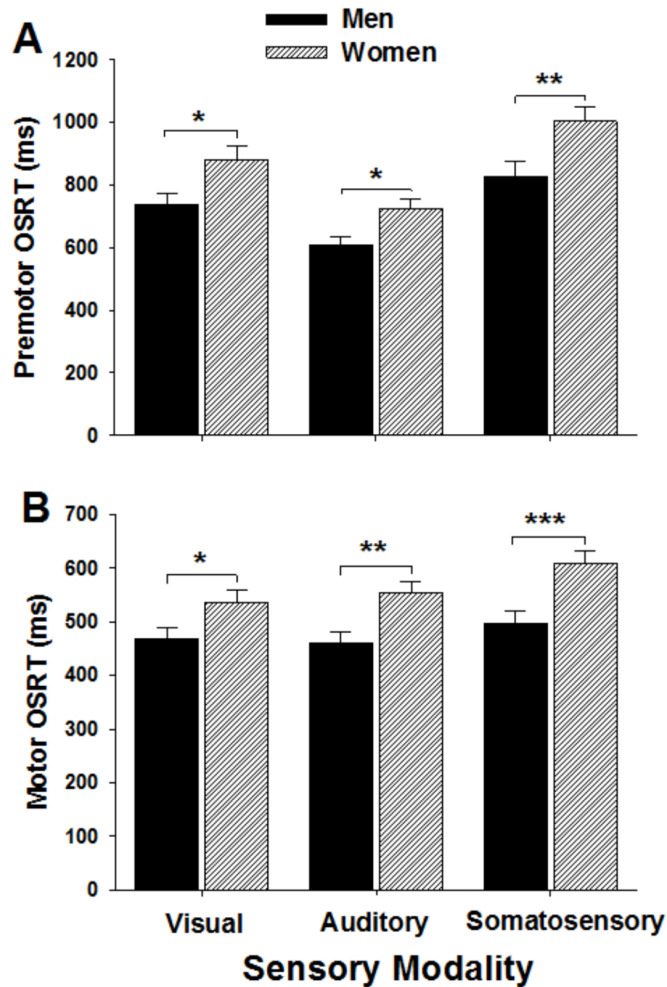


Figure 1. The Premotor (A) and Motor (B) Fractions of the Omitted Stimulus Reaction Time (OSRT) Task according to sensory modality separated by gender \* $p < .03$ ; \*\* $p < 0.01$ ; \*\*\* $p < 0.001$

**DISCUSSION**

The main findings of this study indicate that men are faster than women in both the Premotor and Motor components of the OSRT and in the three sensory modalities, suggesting a male advantage in neural mechanisms involved in timing. This advantage could be more relevant to him for

hunting, than to her, dedicated to planting and harvesting in the ancient times.

The results are not in agreement with the only other study that has compared the OSRT fractions between men and women (Hernández et al., 2005). Nevertheless, it should be highlighted that in the previous study, although not significant, women had

consistently longer Premotor and Motor OSRT than men using lateralised stimuli. This finding motivated the researchers to carry out this study with the main goal of verifying whether any gender differences exist in this task. The present work has several methodological improvements relative to the previous study: the number of participants was more than double, the stimuli were not lateralised but were central, and the tasks were performed only with their dominant hand.

The faster responses for men than women are consistent with the findings in simple and choice RT tasks when fine or gross movements are performed (Sherman, 1978; Adam et al., 1999; Dane & Erzurumluoglu, 2003; Barral & Debu, 2004; Der & Deary, 2006; Spierer et al., 2010; Karia, Ghuntla, & Mehta, 2012). But as it was mentioned before, others report no gender differences (Marmaras, Vassilakis & Dounias, 1995; Roeckelein, 1972; Teleb & AlAwamleh, 2012; Ayala et al., 2014; Hong et al., 2014). The gender differences in the Premotor fraction could be explained as changes in brain function between men and women, who employ different information and processing strategies to measure time (Adam et al., 1999; Spierer et al., 2010). An understanding of gender differences is of value in many ways. It is interesting to test the acute effects of alcohol in the Premotor and Motor fractions of the OSRT in females, as they were reported in males (Hernández et al., 2006). However, before female alcohol experiments are developed, baseline (free-drug) values must be defined

to provide guidance in deciding whether an observed change due to alcohol is within the boundaries of assessment error or is a true change. In other real life situations, differential reactions to an omitted stimulus could help music band directors select better music players under scientific bases or coaches design strategies to optimise athletes' training.

The Premotor times of the OSRT were slower than those found in the traditionally simple or choice RT tasks. This is consistent with the fact that response time increases with higher cognitive loads (Kosinski, 2013). In the OSRT task, a person must not react when a sudden stimulus appears but only when the next stimulus fails to arrive. Thus, the triggers of the behavioural response are internal cognitive processes related to attention, mental chronometry, and decision making. All these triggers lead to higher cognitive load of the OSRT task. Moreover, difficulty determining that the expected stimulus did not occur is likely to increase as the stimulus takes place at a slow rate (2 seconds).

This paper is in agreement with the study of Hernández et al. (2005), which used the OSRT task, and also with many other studies (Brebner & Welford, 1980; Kosinski, 2013) which used conventional simple and choice RT tasks in showing faster responses when auditory stimuli were applied. Sanders (1998) reported this pattern persists, regardless of whether the subject is asked to provide a simple response or a complex response. Unfortunately, comparison with other OSRT results is not



possible as no further studies have examined the Premotor and Motor fractions of OSRT with multisensory stimuli.

The male advantage in the Motor fraction demonstrated in this paper is consistent with other results (Blackburn, Riemann, Pauda, & Guskiewics, 2004). Gender comparison Blackburn, et al., 2004; Granata, Wilson, & Padua, 2002), and the idea that motor time is related to the rate of muscle force production and indirectly measures muscle-tendon unit stiffness (Blackburn, Bell, Norcross, Hudson, & Engstrom, 2009) is similarly consistent with the literature. Men have larger motor units due to their larger muscles, which generate a higher force and movement velocity. Male athletes' and trained individuals' faster responses support this assumption (Arito & Oguri, 1990; Ervilha et al., 2014; Hascelik, Basgoze, Turker, Narman, & Ozker, 1989; Spierer et al., 2010). The results found slower responses to somatosensory stimuli but no differences between the visual and auditory stimuli. The longer duration of the Motor fraction based on behavioural criteria may be attributed to its inclusion of the time to complete a precise key press response. This measure of Motor time assesses the speed and adequacy of the motor response itself, and does not distinguish the onset of a muscle action potential.

One of the potential limitations of the current study is the age distribution of the participants, which was very narrow. Thus, the generalisability of the findings to a broader population must be explored. It is

also important to reproduce this experiment using the left hand and the EMG to separate the Premotor and Motor fractions. Additionally, further studies comparing gender changing stimulus parameters, health conditions, previous training, and drug use, will provide new knowledge to the omitted stimulus task.

## CONCLUSIONS

In conclusion, the main finding of this replication study was that gender differences do exist in response to auditory, visual, and somatosensory stimuli in the omitted stimulus reaction time task. The men were quicker to respond to both Premotor and Motor fractions than women in the three sensory modalities with the dominant hand. This suggests that the male and female brain employs different strategies to drive some internal process such as timing and expectation in order to trigger a behavioural reaction.

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