SEX DIFFERENCES IN VISUAL REACTION TIME: EFFECT OF SPORT PARTICIPATION AND DRIVING

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ABSTRACT

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The purpose of this study is to investigate whether sport participation and driving has any effect on the differences between sexes in visual reaction time (RT). There were three groups (control, exercise, driver), and 20 males and 20 females in each group. The sport participation group was athletes from taekwondo were training at least for five years, minimum three days per week throughout the year. The driver group was males and females were working as representatives of companies and driving at least 20.000 km. annually for the last four years. Each participant was asked to read and sign informed consent and information form at the beginning of the study. Participants were measured three times for simple visual RT, simple visual RT with movement, two and three visual choices RTs for both hands. Descriptive statistics was performed for the four measures according to the groups and sexes. Group and sex differences were examined with MANOVA. The result indicated statistically significant interaction between sex and group for both hands in favor of males for most of the comparisons. Significant differences were also found between three groups and between two sexs for both hands. This study indicated that long term sport participation requiring visual information and driving extensively shorten visual reaction of the participants compared to their counterparts who were not acting in sport and driving.

Keywords: Visual Reaction Time, Sex Difference, Sport Participation, Driving

ÖZ

CİNSİYETLER ARASINDAKİ GÖRSEL REAKSİYON ZAMANI FARKLARI: SPOR KATILIMININ VE ARAÇ KULLANMANIN ETKİSİ

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Bu çalışmanın amacı, spor katılımının ve araç kullanmanın görsel reaksiyon zamanında cinsiyetler arasındaki farka etkisinin olup olmadığını araştırmaktır. Çalışmada üç grup (kontrol, egzersiz, sürücü) ve her grupta yirmi erkek ve yirmi bayan vardır. Egzersiz grubu tekvandodan sporcular olup, en az beş yıl süreyle, yıl boyunca minimum haftada üç gün antrenman yapmışlardır. Sürücü grubu, şirketlerde represant olarak çalışan erkek ve bayanlardır ve son dört senedir yıllık en az 20.000 km. araç kullanmaktadırlar. Her katılımcı, çalışmanın başında gönüllü katılımcı ve bilgi formunu okumuş ve imzalamıştır. Katılımcıların, her iki elleri için de üç defa olmak üzere, basit görsel reaksiyon zamanı, hareket zamanlı basit görsel reaksiyon zamanı, ikili ve üçlü çoklu reaksiyon zamanları ölçülmüştür. Betimsel istatistik, dört ölçüm için, gruplara ve cinsiyetlere göre yapılmıştır. Grup ve cinsiyet farkları MANOVA ile incelenmiştir. Karşılaştırmaların çoğunda erkeklerin lehine olmak üzere, her iki el için de cinsiyet ve grup arasında istatistiksel olarak anlamlı etkileşim bulunmuştur. Aynı zamanda, üç grup arasında ve iki cinsiyet arasında da her iki el için de anlamlı farklar bulunmuştur. Bu çalışma, görsel bilgi gerektiren spora uzun süre katılan ve yoğun araç kullanan katılımcıların, sporda ve araç kullanımında rolü olmayan benzerlerine kıyasla, görsel reaksiyon zamanını kısalttığını göstermiştir.

Anahtar Kelimler: Görsel Reaksiyon Zamanı, Cinsiyet Farkı, Spor Katılımı, Araç Kullanımı

To My Parents

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CHAPTER 1

INTRODUCTION

Reaction time has a long history as a popular measure of human motor skill performance (Magill, 2004). Its applicability to everyday components of life and motor function has supported its practicality in research (Kujala, & Taimela, 1992). Recent studies investigated reaction times from several aspects (Lord et al., 2003; Reimers, & Maylor, 2006; Edinger, Glenn, Bastian, & Marsh, 2000; Hardy, & Hinkin, 2002). Reaction time has been associated with motor performance. Thus, the researchers were mostly interested in the areas that correspond the need of human potential and performance (Collardeau, Brisswalter, Vercruyssen, Audiffren, & Goubault, 2001; Mcmorris, Sproule, Draper, & Child, 2000). The most notable studies on physical education and sport suggested that sport and exercise participation decreases the reaction times (Ando et al., 2005; Davranche, Burle, Audiffren, & Hasbroucq, 2005; Xu, Li, & Hong, 2005; Kokubu, Ando, Kida, & Oda, 2006).

There are also plentiful studies investigating the relation of reaction time and age (Sparrow, Begg, & Parker, 2006; Der, & Deary, 2006), and sex (Reimers et al., 2006; Yagi, Coburn, Estes, & Arruda, 1999). They generally found consistent results whereas some of them found inconsistent results. Some researchers elucidated the subject of what conditions affect the reaction times. Those conditions include caffeine (Duinen, Lorist, & Zijdewind, 2005), energy intake (Ainslie et al., 2003), energy drinks (Alford, Cox, & Wescott, 2001), alcohol (Hernandez, Vogel-Sprott, Huchin-Ramirez, & Aké-Estrada, 2005), drug (Liu, Zhou, Li, Ma, & Hu, 2006), cigarette (Escher, Tucker, Lundin, & Grabiner, 1998), nutrition state (ShukittHale, Askew, & Lieberman, 1997), sleep deprivation (Scott, McNaughton, & Polman, 2006), fatigue (Paasuke, Ereline, & Gapeyeva, 1999), stimulus-response compatibility (Falkenstein, Willemssen, Hohnsbein, & Hielscher, 2006) and so on. While those effects considered seperately by the researchers, mostly simple and choice reaction times were examined on the course of their effects and relations, in the past(Der, & Deary, 2006; Collardeau, Brisswalter, & Audiffren, 2001; McMorris, & Keen, 1994; Chmura, Nazar, & Kaciubauscilko, 1994; Arcelin, Delignieres, & Brisswalter, 1998). To date, it seems that a study about effect of driving on reaction times is necessary and has been suggested valuable by Silverman (2006) because of the absence of the driving effect investigations on reaction times among previous researches.

1.1. Purpose

The purpose of this study is to investigate whether sport participation and driving has any effect (or variable effect) on the difference between sexes in visual reaction time.

1.2. Research hypotheses

The hypotheses of the study were as follows:

Primary hypotheses:

- There was no statistically significant sex and group interaction between males and females of control, exercise, and driver groups.
- There was no statistically significant difference between the reaction time scores of males and females.
- There was no statistically significant difference between the reaction time scores of control, exercise, and driver groups.

Secondary hypotheses:

- Simple reaction times were not statistically better than the choice reaction times for all groups and sexes.
- Dominant hand reaction times were not statistically better than the non-dominant hand reaction times for all groups and sexes.

1.3. Significance of the study

Studies on reaction time have shown that there is a decrease in the reaction time differences between males and females. There are probably some factors that facilitate the decrease. To investigate the factors decreasing sex differences in reaction time is important for future studies. If those factors could be confirmed, they might be used to eliminate the difference of reaction times between males and females. Exercise as a well-known factor that affects reaction times is important to investigate sex differences. Also, driving could be a factor that causes a decrease in the reaction time differences between males and females. If driving is a factor that diminishes that difference, then it is important to count it in the studies investigating the reaction time. Driving might be a factor that affects reaction time, and a control variable for future studies related with reaction time.

Finally, to determine the factors decreasing reaction time differences among sexes may bring the sexes to same level of performance. In addition, to see the effect of exercise and driving can develop a quicker response in competition, thus enhancing players' skills within the sport and improving the success of the team.

To date, there seems to be no visual reaction time studies conducted on sex differences with the effect of driving. Also, there is a need for studies investigating sex differences due to sport participation.

1.4. Limitations

- This study was limited with the subjects between 18-35 years of age.
- The full representation of the sport branches is in question. Because only taekwondo as a sport was chosen for sport participation group. Taekwondo was chosen because visual reaction time is a dominant factor for performance.
- A report on eye physiology was not requested from the participants. They were accepted as normal on eye physiology.

CHAPTER 2

LITERATURE REVIEW

This section includes the clarification about reaction time and related topics. First, reaction time and the sub topics of it are defined and the relation on the topic is examined, then, importance of it is given. Measurement techniques in the previous studies are mentioned. Also, some factors affecting reaction time is discussed.

2.1. Reaction time

2.1.1. Definitions

Reaction time is the interval between the onset of a stimulus and the initiation of the action (Coker, 2004; Magill, 2004; Oxendine, 1968). It is the speed with which one reacts to a signal (Rosenbaum, 1991). Similarly, Dickstein, Hocherman, Amdor and Pillar (1993) defined “reaction time” as the time between the signal and movement initiation in their study about the patients with hemiparesis. Reaction time includes only the time before movement begins but not any movement related action (Magill, 2004).

Reaction time has three varieties, which are simple reaction time, choice reaction time and discrimination reaction time (Magill, 2004). When there is only one signal and only one response, reaction time situation is simple reaction time. It is the simplest model of measuring the central nervous system function (Liu et al., 2006). The condition of simple reaction time does not require a decision (Neubauer, & Knorr, 1997). But on the other hand, in choice reaction time, there is more than one signal and each signal has a specified response (Magill, 2004; Oxendine, 1968; Schmidt, & Wrisberg, 2004). To date, seldomly searched variety of reaction time by the researchers is the discrimination reaction time which is viable when there is more than one signal but only one response (Magill, 2004; Oxendine, 1968).

Silverman (2006) typically defined simple reaction time in his meta-analysis as the duration of time between the onset (or offset) of an imperative stimulus and the initiation of a specified response, and after that made clear of his opinion which was that classical definition of simple reaction time fails to take note of the fact that there are two basic variants of it. Assuming the manual response is made to the imperative stimulus, the first variant, the participant presses a button, key, switch (the manipulandum) that can be contacted without having to make reaching response with the arm. The othet variant, the manipulandum is placed at a distance from the hand, thereby requiring a reaching response with the arm. Also, he stated that far fewer studies have used the second variant and for this reason, he restricted the analysis to those with the first variant.

Two types of reaction time commonly utilized in research are visual and auditory reaction time. Visual reaction time has two components. First component is the premotor time and is a period of time between the onset of the stimulus signal and the beginning of the muscle activity whereas the second component is the motor time and is the period of time from the increase in muscle activity until the actual beginning of observable limb movement (Magill, 2004).

There are also two additional performance measures. They are movement time and response time. Movement time is the interval of time between the initiation and the completion of an action. This means that movement time begins when reaction time ends. However, response time is the total time interval, involving both reaction time and movement time (Coker, 2004; Magill, 2004).

2.1.2. Importance of reaction time

Many researches have been investigated on reaction time from various aspects (Collardeau, Brisswalter, Vercruyssen, Audiffren, & Goubault, 2001; Ando et al., 2005; Sparrow, Begg, & Parker, 2006; Reimers et al., 2006). Most studies designed to determine the relationship between reaction time and performance, have compared individuals of different ability or experience in athletics (Oxendine, 1968). Reaction time is an index of quickness of the body, which is an important factor in the ability for physical exercise and essential not only in many kinds of sporting activities, but also for the physical activities of daily life (Ishijima, Hirai, Koshino, Konishi, &

Yokoyama, 1998). Quick reaction time is as important as an individual's force generating activities in many sports and daily activities (Yeung, Au, & Chow, 1999). Reaction time is an important determinant to evaluate psychomotor performance and it is one of the variables involved in psychomotor skill (Ando et al., 2005). Reimers et al. (2006) declared that further research is necessary to determine the factors affecting sex differences with practice on reaction time. Also, the recommendation of the article of Silverman (2006) was to determine the factors that effect the size of the sex difference in reaction time. The strength of Silverman's (2006) study was that the meta-analysis included a large number of studies (21) covering 73-years period. The article also argues that there was insufficient evidence to indicate that participation in sport affects reaction time, and there was no evidence to indicate that driving affects reaction time.

Reaction time is one of the important methods used to study a person's central information processing speed and fast coordinated peripheral movement response. Reaction times have been used to measure processing speed, measure attention, processing abilities, types of processing, intelligence, and general knowledge. Strayer and Kramer (1990) point out that controlled processing requires more time to execute as compared to automatic processing. Reaction times, therefore, can be used to distinguish between controlled and automatic processing.

Successful performance in sport requires high level of perceptual ability that includes reaction time task (Mori, Ohtani, & Imakana, 2002). In very general understanding, reaction time measures the human performance (Szalmas, Bodrogi, & Sik-Lanyi, 2006). Reaction time is important measure of information-processing speed (Schmidt, & Wrisberg, 2000). Der and Deary (2003) mentioned that reaction time has played an important role in research on human mental ability for over a century. Reaction time is generally used as a basis for inferring other characteristics by the researchers whereas it can be used as a performance measure to assess how quickly a person can initiate a required action (Magill, 2004). Another important use of reaction time is to assess the capabilities of a person to anticipate a required action and determine when to initiate it (Magill, 2004). Another area that the reaction time has a great deal of importance is on the drivers. Adequate reaction times are crucial for avoiding collisions in traffic (Anstey, Wood, Lord, & Walker, 2005).

2.1.3. Reaction time and movement time relation

Reaction time and movement time are different aspects of human performance and independent measures meaning that, both reaction time and movement time does not predict each other (Magill, 2004). As a consequent of this, a person who has the fastest reaction time may not have the fastest movement time and vica versa (Magill, 2004). But from the aspect of the success, if movement time increases, cause there is direct proportion between them, response time also increases.

Rudisill and Toole (1992) indicated that simple reaction time was faster when performed alone than when it was performed with the simple movement time task. They recommended not taking the measurements with movement time. Since the expectation that simple reaction times will be faster than the simple reaction times with movement was presented, the simple reaction time with movement was measured in the present experiment to see the time difference between them.

2.1.4. Simple versus choice reaction time

In a simple reaction time task the subject is required to make a repetitive, simple response (e.g., button press with the right index finger) to every presentation of a stimulus e.g., flash of light, or hearing a buzzer) that occurs on every trial. In simple reaction time, almost no integration or decision-making is required. However, choice reaction time requires the subject to map a stimulus onto a response. That is, the subject must discriminate the imperative stimulus and select one appropriate responses. In other words, choice reaction time tasks require subjects to make a decision before they respond. For example, the choice may involve pressing a button with the right hand for some stimuli and with the left hand for others. As such, choice reaction time requires greater computational demands of the subject than simple reaction time.

Choice reaction times are usually longer than simple reaction times (Rosenbaum, 1991; Oxendine, 1968). Also a fact about choice reaction time is that it should be reduced by repeated testing of response regardless of which stimulus is assigned to it, if subjects respond more quickly to a stimulus because of their preparation to make a particular response (Rosenbaum, 1991).

The pioneer reaction time study was that of Donders (1868). He showed that a simple reaction time is shorter than a recognition reaction time, and that the choice reaction time is longest of all. An example very much like our experiment was reported by Surwillo (1973), in which reaction was faster when a single tone sounded than when either a high or a low tone sounded and the subject was supposed to react only when the high tone sounded.

Miller and Low (2001) determined that the time for motor preparation (e.g., tensing muscles) and motor response (in this case, pressing the spacebar) was the same in all three types of reaction time test, implying that the differences in reaction time are due to processing time.

In a study by Sheridan in 1981, two experiments were conducted to differentiate between choice visual reaction time and simple visual reaction time. Choice visual reaction time required applying complex thought or decision making when performing a visual reaction time task while simple visual reaction time did not require a complex though process. Both experiments in this study consisted of the same visual reaction time tests; however, Experiment I was a "no preview" test. Subjects in Experiment I were not allowed to view the parameters of the movement they were required to perform. In contrast, subjects in Experiment II were allowed to view and practice the movement parameters until they understood and mastered the task. Two types of stimuli (targets) were presented on a cathode ray tube in each experiment, constant amplitude and variable amplitude. In constant amplitude, the amplitude (size) of the target remained constant and the tolerance (spatial depth) varied. The inverse for variable amplitude was varying amplitude and constant tolerance. Subjects were instructed to wait for the stimulus (the target) to appear on the cathode ray tube. At that time, they moved a lever, which controlled a cursor on the cathode ray tube from the resting position to the target area, as quickly and as accurately as possible. Results demonstrated that visual reaction times in the subjects who previewed the response programming process, Experiment II, were significantly quicker than the non-preview subjects in Experiment I. In the simple reaction time tests, the difference was not significant between the subjects in Experiment I and II.

However, in the choice visual reaction time tasks, subjects were much quicker in Experiment II, when they were allowed to preview the response parameters prior to the testing.

2.1.5. Auditory versus visual reaction time

Many researchers have confirmed that reaction to sound is faster than reaction to light, with mean auditory reaction times being 140-160 msec and visual reaction times being 180-200 msec (Woodworth, & Schlosberg, 1954; Welford, 1980; Brebner, & Welford, 1980). Perhaps this is because an auditory stimulus only takes 8-10 msec to reach the brain (Kemp, 1973), but a visual stimulus takes 20-40 msec (Marshall *et al.*, 1943). Differences in reaction time between these types of stimuli persist whether the subject is asked to make a simple response or a complex response (Sanders, 1998). For about 120 years, the accepted figures for mean simple reaction times for college-age individuals have been about 190 ms (0.19 sec) for light stimuli and about 160 ms for sound stimuli (Welford, 1980; Brebner and Welford, 1980).

2.1.6. Hand dominance in reaction time

The results of Boulinquez and Bartélémy (2000) and Bartélémy and Boulinquez (2001, & 2002) all supported the idea that the left hand should be faster at reaction times involving spatial relationships (such as pointing at a target). It was because of the fact that the left hemisphere of the brain is regarded as the verbal and logical brain, and the right hemisphere is thought to govern creativity and spatial relations, among other things. Also, the right hemisphere controls the left hand, and the left hemisphere controls the right hand. Dane and Erzurumluoglu (2003) found that in handball players, the left-handed people were faster than right-handed people when the test involved the left hand, but there was no difference between the reaction times of the right and left-handers when using the right hand. Finally, although right-handed male handball players had faster reaction times than right-handed women, there was no such sexual difference between left-handed men and women. The authors concluded that left-handed people have an inherent reaction time advantage. In an experiment using a computer mouse, Peters and Ivanoff (1999) found that right-handed people were faster with their right hand (as expected), but left-handed people were equally fast with both hands. The preferred hand was generally faster. However, the reaction time advantage of the preferred over the non-preferred hands was so small that they recommended alternating hands when using a mouse. Bryden (2002), using right-handed people only, found that task difficulty did not affect the reaction time difference between the left and right hands.

2.1.7. Reaction time measurements

Researchers have named three basic kinds of reaction time experiments (Luce, 1986; Welford, 1980). First, in simple reaction time experiments, there is only one stimulus and one response. 'X at a known location,' 'spot the dot,' and 'reaction to sound' all measure simple reaction time. Second, in recognition reaction time experiments, there are some stimuli that should be responded to (the 'memory set'), and others that should get no response (the 'distractor set'). There is still only one correct response. 'Symbol recognition' and 'tone recognition' are both recognition experiments. Third, in choice reaction time experiments, the user must give a response that corresponds to the stimulus, such as pressing a key corresponding to a letter if the letter appears on the screen. The reaction time program does not use this type of experiment because the response is always pressing the spacebar.

Strayer and Kramer (1990) used manual reaction times to assess the attentional demands of controlled and automatic processing. In this study, subjects were required to manipulate a joystick in response to stimuli on single and dual tasks. If the target was present they were instructed to move the joystick to either the right or left, and if the target was absent they were instructed to move the joystick in the opposite direction. Both speed and accuracy were used to determine the type of processing utilized by each subject. They found that speed and accuracy were diminished from single to dual task performance. Manual reaction times were also used by Shulman, Russell, and Rastatter (1986) to measure syntactic decoding abilities of teaming disabled children versus that of norm, children. They used left and right-hand response plates to present the visual stimuli. Eac child was instructed to touch the response plate that corresponded to the auditory stimulus. Reaction times were then compared to determine the linguistic processing abilities of each child. There were no significant differences in reaction times between learning disabled and normal children. Shulman, et al. (1986) concluded that the task was not complex enough to reveal processing differences between the groups. Hopkins, Morris, Savage-Rumbaugh, and Rumbaugh (1992) used manual reaction times to establish hemispheric dominance for meaningful and non-meaningful symbols in language-trained chimpanzees. In this study the participants were required to keep their finger on a button placed directly in front of them until the stimulus was presented. Reaction times were measured from the presentation of the stimulus to the removal of the finger from the button. Analysis of reaction times for this study demonstrated left hemisphere advantages when stimuli were presented in the right visual field. Fletcher, Smith, and Hasegawa (1985) compared the response times of normal hearing versus hearing-impaired children to visual stimuli. In the study, vocal reaction times were compared between the two groups to determine if there was a systematic relationship between central speech processes and phonetic complexity of a speech task. There were four tasks that utilized vocal responses. The first task involved responding vocally with an approximation of the "uh" sound to a lighted visual prompt on a screen. The second task involved saying the word "one" in response to a lighted screen signal. The third task consisted of a multiple-word counting response elicited by a single digit prompt, and the final task was to name a digit projected on a screen. Fletcher et al. (1985) reported that no differences were noted among the groups for the first task, but that differences in performance began to emerge when the phonetic and verbal demands of the tasks increased. Children with hearing impairment had prolonged latencies that were greater than those of the normal hearing subjects, suggesting that the hearing impaired children were less adept at central phonetic processing.

There are various measurement devices for reaction times and some of them were presented in this section. There is stimulus discrimination test (SDT) for the study of Neubauer and Knorr (1997) that allows the seperation of elementary cognitive processes in choice reaction time tests. This test requires the participants to sit in front of a computer monitor and their index fingers to rest on two buttons of a response-console. The warning stimulus was appeared for 100msec and after a foreperiod (between 1000 and 2000 msec), the reaction stimulus replaced the fixation cross. Another study used standard computerized apparatus, which run with a series of 20 red light stimuli, each lasting 18ms, and randomized in sequence at intervals ranging from 2 to 5 s to measure the simple visual reaction time (Iudice et al., 2005). In the study of Leonard (1959), there are small vibrators, which allows subject to press his/her finger on when the vibration came. McMorris et al. (2006) used a technique, which is similar to the present study. They measured the 4-choice visual reaction time. There was a digitimer (Queens- way Scientific, Fareham, UK), which had four lights in a line and four buttons, one below each light. A device which has a warning stimulus followed 2 s later by an imperative stimulus (S1 – S2 reaction time task) used by Kamijo et al. (2004). Davranche and Audiffren (2004) used a cycle ergometer (Ergoline 800S) to measure the choice reaction time. In that study, the choice reaction time task involved operating two levers. Their resistance was controlled by an electromagnetic brake of constant voltage with hand as quickly as possible to a visual stimulus shown in a 200-ms time-frame. Similarly in testing, Davranche, Burle, Audiffren and Hasbroucq (2006) used the same technology to assess the simple reaction time. Also, reaction time can be assessed via noting as the duration between the stimulus and the electromyographic (EMG) onsets (Endo, Kato, Kizuka, & Takeda, 2006). Beside all these measurement techniques, there are measurement tests used according to the cognitive ability, for example, for abstract reaction time, respond to square (McKnight, & McKnight, 1999), for meaningful reaction time, respond to brake lights (McKnight et al., 1999), for simple and complex reaction time, computer-generated neurobehavioral evaluation system (Odenheimer et al., 1994) and for choice reaction time, respond to nature of stimulus (McKnight et al., 1999) tests were used. Philip et al. (2005) used 10-minute simple reaction test on a PALM personal orginazer.

2.1.8. Factors affecting reaction time

Many factors affect reaction time. The state of the subject, the nature of the stimulus, the nature of the response, the relations among these factors are some of them (Rosenbaum, 1991), number of response choices, psychological refractory period (Coker, 2004), number of stimulus-response alternatives, practice, predictability of the upcoming events (Schmidt, & Wrisberg, 2004), stimulus-response compatibility, anticipation, (Coker, 2004; Schmidt, & Wrisberg, 2004), stimulation of the sense organs, intensity of the stimulus, height of readiness, age, sex, drugs and alcohol (Oxendine, 1968) are known ones. Also there are articles about fatigue, sleep state, occlusal support, nutrition state, caffeine, energy drink, drug, cigarette effects on the reaction times.

2.1.8.1. Sex

At the risk of being politically incorrect, in almost every age group, males have faster reaction times than females, and female disadvantage is not reduced by practice (Welford, 1980; Adam et al., 1999; Dane and Erzurumlugoglu, 2003; Der and Deary, 2006). Engel, Thorne, and Quilter (1972) reported a reaction time to sound of 227 msec (male) to 242 msec (female). However, things may be changing, Silverman (2006) reported evidence that the male advantage in visual reaction time is getting smaller (especially outside the US), possibly because more women are participating in driving and fast-action sports. In a surprising finding, Szinnai, Schachinger, Arnaud, Linder, and Keller (2005) found that gradual dehydration (loss of 2.6% of body weight over a 7-day period) caused females to have lengthened choice reaction time, but males to have shortened choice reaction times. Adam et al. (1999) reported that males use a more complex strategy than females. Barral and Debu (2004) found that while men were faster than women at aiming at a target, the women were more accurate. However, Jevas and Yan (2001) reported that age-related deterioration in reaction time was the same in men and women.

Men and women often differ in education, occupation, and related lifestyle variables that are closely associated with physical function (Buchman, Wilson, Bienias, & Bennett, 2005). Some studies on sex differences in reaction times begin with the hypothesis that men and women might employ different information processing strategies on some tasks (Adam, Paas, Buekers, Wuyts, Spijkers, & Wallmeyer, 1999). Their study, which had 12 male and 12 female participants, resulted a near-significant overall reaction time advantage for male participants. The participants had performed 2 and 4 choice, compatible and incompatible choice reaction time task that required a verbal response to a spatial location target stimulus. They pointed out that the sex differences in reaction time performance found in their results might reflect differences in processing strategy.

Silverman (2006) clarified that women have a natural advantage over men in reaction time because women are on average smaller than men and so, the neural impulses involved in the production of a motor response have less far to travel in women than in men.

With the 16 male and 16 female participants for the control group and 32 male and 34 female participants for the heroin dependent patients group, the study of Liu et al. (2006) was conducted to see the heroin effect on simple reaction time and if it was sex related. They found that there was significant slowing of the simple reaction time both for male and female heroin dependent patients at 1 – 3 months from withdrawal, meaning that heroin abuse has detrimental effect on simple reaction time. Moreover, slowing of simple reaction time continued after 3 months of heroin withdrawal in females but not in males. Also, another relevant result of the study was that the mean simple reaction time in normal male subjects was shorter than that in females.

Der et al. (2006) noted that there are significant sex differences most notably for choice reaction time variability. Silverman's (2006), meta-analysis article showed that males outperformed females on the time tasks. He committed his study to determine the change in the magnitude of the sex differences across time. Reimers et al. (2006) found about sex differences on reaction time that female reaction time standart deviation was larger than male reaction time standart deviation. Also they showed an interaction between sex and trial number. Female reaction times started slower than males' and became faster as the block progressed (Reimers & Maylor, 2006). However, Linford, Hopkins, Schulthies, Freland, Draper and Hunter (2006) found no sex difference and interaction between sexes in reaction times.
All similar results illustrated that sex differences on reaction times needed more investigations.

2.1.8.2. Age

Simple reaction time shortens from infancy into the late 20s, then increases slowly until the 50s and 60s, and then lengthens faster as the person gets into his 70s and beyond (Jevas and Yan, 2001; Luchies et al., 2002; Rose, Feldman, Jankowski, & Caro, 2002; Der and Deary, 2006). Luchies et al.(2002) also reported that this age effect was more marked for complex reaction time tasks, and Der and Deary (2006) concurred. Welford (1980) speculates on the reason for slowing reaction time with age. When troubled by a distraction, older people also tend to devote their exclusive attention to one stimulus, and ignore another stimulus, more completely than younger people (Redfern, Muller, Jennings, & Furman, 2002). Lajoie and Gallagher (2004) found that old people who tend to fall in nursing homes had a significantly slower reaction time than those that did not tend to fall. Older adults are known to respond slower on most speeded tasks than young adults.

There is a decline in many cognitive abilities, including reaction times that are relevant to performing complex tasks such as driving even in normal aging (Anstey et al., 2005). Increasing task complexity strengthens the effect of age on the reaction time studies (Lupinacci, Rikli, Jones, and Ross, 1993). They also found that there are no age and activity level interactions. Young athletes continue to improve their psychomotor performance during exercise even at heavy workloads exceeding anaerobic, and plasma adrenalin thresholds according to the conclusion of the study of Chmura et al. (1994). Sparrow et al. (2006) found older males had significantly longer reaction times than the younger males both in single task and dual task. Reimers et al. (2006) found in their study about gender effects on reaction time and trial-to trial performance, that, relative to the youngest (15-19) age group, the 20-29 age group was the less slow, 30-39 age group was the middle slower and the 40-66 age group was the slowest group. The datum of study of age differences on the reaction times showed that there are little slowing in reaction times until aroung 50 years-old on simple reaction time, wheras choice reaction time slows throughout the adult age range (Der et al., 2006). In addition, visual reaction time is longer during childhood compared to the years between ages 20-30 when it is at its shortest, and after age 31 visual reaction time increases or becomes slower (Basgoze, Hascelik, Narman, Ozker, & Turker, 1989).

2.1.8.3. Training

Exercise can affect reaction time. The role of exercise is studied from many aspects (Barnett, Smith, Lord, Williams, & Baumand, 2003; Junge, Dvorak, Rosch, Graf-Bauman, Chomiak, & Peterson, 2000). Some researches show that reaction time results show clear facilitation during exercise (Yagi et al., 1999; Ando, Kida, & Oda, 2002). The result of the study of Ari, Kutlu, Uyanık, Taneli, Büyükyazı and Tavlı (2004) indicated that a long-term exercise decreased reaction time. Two types of exercise group which are that agility and stretching/weight-shifting groups improved on step reaction time with the effect of exercise where agility group had greater improvements in the study of Marigold et al. (2005). The study of Tsang and Hui-Chan (2004) showed in their stability test that Tai-Chi practitioners and golfers had faster reaction time than elderly control subjects. Also, after the age sixties, exercise affects reaction time positively (Lord et al., 2003; Zisi, Michalopoulou, Tzetzis, & Kioumourtzoglou, 2001). Xu et al. (2005) found significant shorter times on older Tai Chi and jogging participants than on no-exercise group on the reactions. Un and Erbahçeci (2001) stated in their conclusion that sport is a valid and effective means of training which affects the reaction time positively founding in their result that reaction time is smaller in trainable mentally retarded children. McMorris, Tallon, Williams, Sproule, Draper, Swain, Potter and Clayton (2003) researched for the question that if increases in plasma concentrations of adrenalin and nor-adrenalin during exercise and power output act as predictor variables of reaction and movement times during exercise. They stated according to their results that those variables are not significant predictors of reaction time, but only the power output was a significant predictor of movement time. Therefore, since this conclusion determines that the exercise is certainly effective on the movement time, the exercise group is expected shortened reaction times at least in the choice reaction times - because there are movement times- and simple reaction time with movement time. However, Kubesch, Bretschneider, Freudenmann, Weidenhammer, Lehmann, Spitzer and Gron (2003) found no significant exercise-dependent alterations in reaction time in the control group, but they found significant decrease in mean reaction time in the depressive patients group. Similarly, Taniguchi (1999) found that practice did not shorten the reaction time for both hand measurements. But there is the possibility that this result might be caused by the insufficient number of participants, which were 4 female and 23 male to be divided into 4 groups. Consistent with the idea that this topic also needs some investigations, Mcmorris et al. (2000) found no significant exercise effect on voice and whole-body reaction times measuring the participant's speed and accuracy of response via soccer test. They recommended in their study for further resarch that to replicate using more complex skill tests and discontinuous exercise protocols rather than continuous ones. The study of Endo et al. (2006) had 20 right handed athlete (10 males) and non-athlete (10 males) and the age range was 23-33 years old, testing primary motor cortex activity during a reaction time task to examine the appearance of motor cortex activity that synchronized with the stimulus presentation. They set the athlete definition as playing one's respective sport for at least the previous 3 years. After computing their data, they found no significant difference between the reaction times of athletes and those of non-athletes. They explained this unexpected result as the result of insufficient number of subjects to reliably discuss the reaction time difference. But they also found a significant difference on the stimulus synchronous motor cortex activity (SSMA) of athlete group than that of non-athlete group. In addition, the difference between the reaction times of the SSMA and non-SSMA groups was larger than the difference between the reaction times of the athlete and non-athlete groups and in their view, this result suggested that the SSMA might cause to shorten reaction times. They concluded that long-term physical training promotes motor cortex activity and the effects of reactive task repetition were more clearly apparent in the motor cortex activity of the athletes. Simonen, Videman, Battie and Gibbons (1998) found small effect of exercise on the reaction time. Since they reached the conclusion that health promotion exercise is unlikely to affect reaction time, they think that reaction time may be significantly affected only by vigorous, frequent exercise. But, Audiffren, Brisswalter, Brandet and Bosquet (1998) stated no significant variation of simple reaction time with exercise intensity was observed. They also found that simple reaction time during cycling task was higher than at rest.

Similar with the general results of the studies on exercise and sport effects on reaction time, Rudisill and Toole (1992) found that the six-month physical activity program prevented the slowing of the subject's simple reaction time. Davranche et al. (2006) tested the influence of the exercise during simple reaction time since their literature search indicated that exercise influenced peripheral processes during choice reaction time. They had 12 experienced decision-making sports players (5 females and 7 males, aged 22-50). Although their numbers of participants were relatively not enough and the age interval was too broad, they reached consistency with the general tendency of such simple reaction time studies in their result that exercise improves simple reaction time performance. They also found that mean movement time was shorter during exercise than at rest. Exercise shortens reaction time without affecting its variance is another significant result of their study. Collardeau, Brisswalter and Audiffren (2001) explained the improvement in reaction time with the prolonged exercise according to their results. McMorris et al. (1994) found that simple reaction time was significantly slower during maximal exercise than in the rest and 70% workload exercise conditions, which did not differ significantly from each other. Brisswalter, Arcelin, Audiffren and Delignieres (1997) found significant physical fitness effect on decreasing simple reaction time during exercise, whereas there is no significant difference after exercise. Linford, Hopkins, Schulthies, Freland, Draper and Hunter (2006) showed that neuromuscular training decrease the reaction times. Their training program was for 6-week. These results illustrate that this topic needs more investigations.

Simple tasks, such as simple reaction time tasks are not always affected positively by physical exercise (Davranche et al., 2004). They stated that the timing of cognitive tests' application, which can be during or after the exercise, was also a decisive factor because of the fact that physiological changes quickly return to basal values. For instance, Mori et al. (2002) found no significant difference in simple reaction time task between the karate group and the novice group whereas there was significant difference in choice reaction time task between the groups. Although having this result, it might be useful to state that the number of participants was low as being six karate athletes and seven novices.

Immediately after physical exercise, reaction time decreases (Junge et al., 2000). Junge et al. measuring the reaction time without the influence of physical exercise and immediately after the 12-minute run, found that reaction time which is immediately after the 12-minute run of high-level players was significantly smaller than that of low-level players. These founding demonstrates that if exercise effect on reaction time will be a considerable item in a study, high-level exercisers required measuring the reaction times. Collardeau, Brisswalter, Vercruyssen, Audiffren and Goubault (2001) found similar result with Junge et al. (2000) which is that choice reaction time performance was improved after 100-min run after CHO-electrolyte ingestion that delay the onset of fatigue and improve endurance performance (Coyle, 1991; Davis, 1996, cited in Collardeau et al., 2001) compared with a placebo group. Paasuke et al. (1999) found no significant changes in the central component of visual reaction time after fatiguing static exercise between the groups of endurance-trained, power-trained and untrained men.

Choice reaction time is better performed at the same time with a sub-maximal exercise than when it is at rest (Davranche et al., 2005). They also suggested that physical exercise shortens reaction time by affecting peripheral motor processes according to their results. The study of Davranche et al. (2004) which had 16 experienced players (7 males and 9 females) in decision-making sports, arrived consistent result with their hypothesis that submaximal exercise which is that the 50% of maximal aerobic power improves the performance on a choice reaction time task. They concluded that exercise at 20% of maximal aerobic power could help to maintain arousal. Also, moderate aerobic exercise causes selective influences on choice reaction times (Arcelin et al., 1998). Arcelin et al. (1998) found a significant underadditive interaction between Time Uncertainty and exercise for the reaction times. This may mean that the time of light or voice coming after commend "ready" may be an effective factor especially for the exercise group.

Among the athletic group of woman participants, performers in different sports differed in speed of movement, but not in reaction time and according to this conclusion, swimmers tended to be the slowest movers, but field hockey, fencing, and tennis performers had no difference in movement speed (Younger, 1959, cited in Oxendine, 1968).

Welford (1980) found that physically fit subjects had faster reaction times. Kashihara and Nakahara (2005) found that vigorous exercise did improve choice reaction time, but only for the first 8 minutes after exercise. Exercise had no effect on the percent of correct choices the subjects made. On the other hand, McMorris et al. (2000) found no effect of exercise on reaction time in a test of soccer skill, and Lemmink and Visscher (2005) found that choice reaction time and error rate in soccer players were not affected by exercise on a stationary bicycle. Davranche et al. (2006) concluded that exercise on a stationary bicycle improved reaction times.

Collardeau et al. (2001a) found no post-exercise effect in runners, but did find that exercise improved reaction time during the exercise. They attributed this to increased arousal during the exercise.

Research findings generally indicate that adding an exercise program to one's daily activity has a positive affect on visual reaction time (Castell & Lord, 1994). As mentioned above, while some investigators claim that aerobic training can positively affect visual reaction time (Edwards & Rikli, 1991), others observed no difference with training (Adam, Janssen, Paas, & Vrencken, 1994). Basgoze et al. (1989) observed that improvements in visual reaction time are positively correlated with physical fitness over an eight week physical conditioning training period.

In 1986, Butchiramaiah, Khan, and Sharma conducted a study comparing the auditory reaction time and visual reaction time of 40 recreational and competitive volleyball players, gender and age not specified. Electrical chrome was used to test simple auditory reaction time and visual reaction time. Competitive players consistently exhibit quicker auditory reaction time and visual reaction time compared to the recreational players. The authors suggested competitive athletes demonstrated a higher level of concentration ability.

Research conducted on athletes has shown visual reaction time to be related to performance in many sports. In a study by Montano and Whitley (1992), visual reaction time and its components, specifically movement time, were measured in college wrestlers. Subjects were instructed to assume a squatting position while facing a wrestling practice dummy. A white light was flashed which alerted subjects that a flash of red light would soon. Upon illumination of the red light, subjects were instructed to make contact with target disk embedded in the center of the practice dummy. The amount of time measured from the flash of red light to the time in which the subject began to move represented visual reaction time, while movement time was measured from the initiation of the movement to the subjects' contact with the blue target. Results of this study did not demonstrate a significant change in visual reaction time and movement time. However, there was a significant correlation, $r = 0.62$, between movement time and the individual win-loss record, ($p < 0.05$). Montano and Whitley believed the significant correlation might be in part due to training the subjects underwent in preparation for competition.

Abernathy (1991) showed that a faster visual reaction time is related to greater success in racquet sports. The testing protocol consisted of 160 temporal (phases in a movement) trials and 160 spatial (relativity to body positioning) trials using composite film. Different types of strokes were filmed using the testing protocol on 20 expert badminton players and 35 novice players. Results from this study indicated that in order for an athlete to be successful, anticipatory strategies were required. Two factors were considered: 1) locating advanced cues, which provide anticipatory information and 2) expert-novice differences in anticipatory cue usage. Anticipatory cues were determined through prediction and preparation accuracy of visual search strategies. This demonstrated that experts had the ability to respond to visual cues quicker and more accurately than novice athletes. By incorporating visual reaction time into sport specific skills, the experts possessed a greater ability to predict speed and direction of their opponents' strokes.

A study by Durst, Harbin, and Harbin (1989) investigated differences between visual reaction time in high school, college, and professional basketball and football players. Ten athletes served as subjects for the study. The procedure of this study required each athlete to stand on a center panel, which consisted of five depressible colored panels (blue, white, black, red, and yellow). A color graphics monitor connected to an Apple II computer flashed one of the five colors on the screen. When a color was flashed, the subjects were instructed to step off of the center panel and depress the corresponding color panel as quickly as possible. After the color panel was depressed, the subjects had to return to the center panel, which in turn, activated the computer to flash another color on the monitor. One trial was comprised of a series of 30 color displays. The time it took for the subjects to depress the color panel was recorded by the internal clock of the computer. Each subject performed three trials, but only the last two trials were averaged. The results indicated that 50% of the high school and college athletes possessed a significantly different reaction time, more than two standard deviations slower, than the professional athletes. The results between sports were not statistically different. It was hypothesized that visual reaction time may be useful in the decision of movement because muscle synchronization may be improved which can minimize overall movement time.

Jenkins and McLeod (1991) wrote a review article that compared two aspects of total reaction time, visual reaction time and visually based timing, in both elite and non-elite cricketers. In this study visual reaction time was the time between the onset of a visual stimulus and the execution of an action. Visually based timing was the ability to perform the appropriate action upon the arrival of an approaching object. The assumption compiled from previous laboratory research on cricketers performing non-sport skill visual reaction time tasks, was that overall reaction time of top-class athletes were not superior to those of the "average" athletes. On the other hand, these top class athletes performed better with their perceptual-motor systems when carrying out the appropriate task or skill within the sport. The highly skilled cricketers were capable of processing visual information and making decisions of movement quicker and more accurately than the less skilled athletes. In the review, Jenkins and McLeod stated that they agreed with results of an experiment conducted by Abernathy and Russell in 1994, which concluded that expert cricketers developed good prediction skills on the basis of visual cues. The authors believed that basic perceptual skills could be mastered with continual practice, which could reduce reaction time in that specific task. In relation to sports, Jenkins and McLeod stated that practice could lead to the formation of perceptual schemata, which could help the player to better understand, remember, and predict what will happen in game situations.

Basgoze, et al. (1989) conducted a study testing the effects of training on physical fitness, auditory reaction time, and visual reaction time in volleyball players. Physical fitness was determined by lean body mass, $V02_{max}$ vital capacity, and a general strength index using the Spartacus Universal Gym machine as a dynamometer. Subjects took part in a physical conditioning program five days a week for eight weeks, which consisted of a warm-up, a weight training session, and concluded with stretching exercises. The warm up lasted for 20 minutes, which was followed by weight training on the Spartacus Universal Gym Machine. The subjects performed 10 repetitions at each station on the Universal Gym Machine, with no rest between each exercise. After the completion of one circuit (one set) the subjects rested for two minutes. The subjects performed a total of three sets. Finally a 20-minute stretch and relaxation period concluded the training. Auditory reaction time and visual reaction time were measured with the Textronics 502A Oscilloscope and Grass 588 stimulator. All measurements were taken before and after the training period. Significant improvement occurred in all components of physical fitness except vital capacity. The subjects increased their $V02_{max}$ and overall strength. Both auditory reaction time and visual reaction time decreased significantly with a mean improvement of 16.25 ± 28.61 and $14.55 + 22.32$ msec, respectively.

In 1996, a study by Lord, Ward, and Williams investigated the effects of exercise on 112 elderly women. Of the 112 women volunteers, 104 were chosen to take part in the study, 65 were assigned to an exercise group and 39 were assigned to a non-exercising control group. Researchers put the exercise group on a 12-month regime to determine how exercise affected dynamic stability including visual reaction time. The exercise group participated in physical activity twice a week, one hour a day, for four, 10-12 week periods. Between each 10-12 week period the subjects had a two-week exercise break. They also had a five-week Christmas break and a five-week summer break. Each exercise session consisted of a five minute warm up period, a 35 minute conditioning period, a 15-minute stretching period, and a five to 10 minute cool down. A variety of exercises were introduced to the women, including aerobic training, balance activities, hand-eye/foot-eye coordination, and strength training. Quantitative stability assessments of maximal balance range (max anterior and posterior lean) and coordinated stability tasks (ability to adjust balance during applied equilibrium disturbance) were tested pretrial, midway through, and at trial completion (12 months). Sensorimotor function assessments of muscle strength (hip flexion/extension, knee flexion/extension, ankle dorsiflexion), neuromuscular control (foot speed), body sway (position displacement with eyes open and then closed standing on the floor and then on foam), and visual reaction time were also measured during the same three periods. Prior to the study, no significant differences between controls and exercisers existed. The exercise group and control group had a maximal balance range of $17.5 + 3.9$ cm and $18.0 + 4.2$ cm respectively, and coordinated stability task measurements of $10.3 + 8.2$ errors and $8.6 + 7.2$ errors. Significant changes developed in the exercise group in both maximal balance range ($F1.79 = 5.99$, $p < 0.05$) and coordinated stability tasks ($F1.79 = 7.98$, $p < 0.01$) halfway through the study, at 22 weeks. The last MANOVA analysis at the end of the 12-month program revealed significant improvement in maximal balance range test ($F = 21.81$, $p < 0.01$) and also coordinated stability tasks ($F = 15.08$, $p < 0.01$). The investigators indicated that the improvements, although significant, were not as drastic in the last half of the experimental period than the first. Composite scores of the sensorimotor function assessments were not listed, however, authors correlated associations between the results of these tests and performance in the quantitative assessments. In maximal range, significant difference occurred in all variables of the strength tests, half of the sway tests (only those performed standing on foam), and visual reaction time. None occurred in neuromuscular control. All assessments of sensorimotor functions had significant correlation in coordinated stability tasks. Correlations in all strength in maximal range were greater than in coordinated stability tasks. During the body sway tests, the difference was much greater in tests with eyes closed (0.37 sec standing on the floor and 0.55 sec standing on foam). Overall visual reaction time was significantly associated with performance in only the coordinated stability tasks ($p < 0.01$) at 0.36 msec. The results of this study suggest that long-term exercise can improve dynamic stability and visual reaction time in the elderly female population.

In 1994, McMorris, and Keen studied the effects of moderate and fatiguing exercises on visual reaction time of recreational athletes. The subjects consisted of eight male and four female recreational athletes, ages 18-22. Fifteen simple reaction time tests were performed on a BBC microcomputer. When the stimulus (a red square) appeared on the screen, the subjects were instructed to depress the spacebar on the keyboard. The subjects took the 15 trial test three times - (1) at rest, (2) at 70% max workload, and (3) maximum workload. Maximum workload was defined as the point, which exhaustion was reached and the subjects were not able to maintain power output. To determine maximum workload, subjects exercised on a bicycle ergometer, starting at 70 RPM with 0.5 kg resistance. After every two minutes, resistance increased 0.3 kg for females and 0.4 kg for males. After maximum workload was determined, 70% max was calculated. Simple visual reaction time tests were first performed after one minute of pedaling. The 70% calculated workload was used as a baseline measure to perform the second succession of simple visual reaction time tests during the exercise session. Finally, the last simple visual reaction time tests were performed when the subjects reached maximum workload. The results using a one-way ANOVA indicated a significant improvement ($p < 0.01$) in simple visual reaction time during exercise; however, there were no significant difference ($p > 0.05$) at maximum workload than at the other two conditions.

2.1.8.4. Stimulus-response compatibility

Spatial compatibility between stimulus and response is an important designator of performance (Falkenstein et al., 2006). Stimulus-response compatibility is an important factor nearly in all kinds of reaction time tasks (Rosenbaum, 1991). Stimulus-response compatibility is the 'naturalness' of the connection between the stimulus and the response (Schmidt, & Wrisberg, 2004). If the stimulus-response alternatives increase, choice reaction time also increases (Hick, 1952; Hyman, 1953). This is a relation known as the Hick-Hyman Law (Schmidt, & Wrisberg, 2000; Coker, 2004; Rosenbaum, 1991). The compatibility of stimulus and response is very important. Rosenbaum (1991) stated the study of Leonard (1959), which is a classical experiment that measures the choice reaction times with vibrators to press on with fingers when it vibrated. According to the result of that study, choice reaction time did not consistently increase with the number of stimulus and response alternatives (Rosenbaum, 1991). However, the point was that the relation between the stimulated finger and the response finger. Leonard (1959) concluded in his study that when the stimulated and response finger were the same, there was compatibility between stimulus and response, however, the stimulated and response finger were not the same. Hick-Hyman Law explained this result that the choice reaction time increases (Leonard, 1959, cited in Rosenbaum, 1991). Falkenstein et al. (2006) stated that when the relative spatial positions of stimulus and response correspond, the response times in choice-reaction tasks are shorter comparing the positions of them do not correspond, even when the spatial relation is irrelevant for the response choice. Beside the stimulus-response compatibility, there is a tendency for a response to have different choice reaction times depending on the other response or responses that can be tested. This is known as response-response compatibility (Rosenbaum, 1991).

2.1.8.5. Other factors

Arousal One of the most investigated factors affecting reaction time is 'arousal' or state of attention, including muscular tension. Reaction time is fastest with an intermediate level of arousal, and deteriorates when the subject is either too relaxed or too tense (Welford, 1980). That is, reaction time responds to arousal as follows (Figure 1):

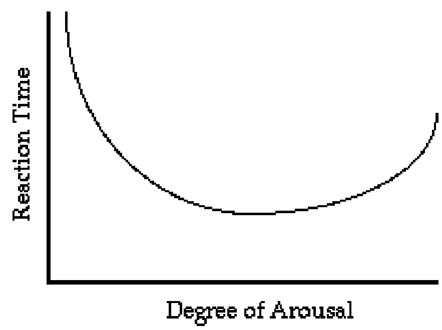

Figure 1. The Relationship between Reaction Time and Degree of Arousal

Etnyre and Kinugasa (2002) found that subjects who had to react to an auditory stimulus by extending their leg had faster reaction times if they performed a 3 second isometric contraction of the leg muscles prior to the stimulus. It might be expected that the muscle contraction itself would be faster (because the muscle was warmed up, etc.), but what was surprising was that the precontraction part of the reaction time was shorter too. It was as if the isometric contraction allowed the brain to work faster. The same conclusion was reached by Masanobu and Choshi (2006). They found that moderate muscular tension (10% of maximum) shortened the precontraction reaction times of subjects who were asked to extend either their left or right leg in a choice reaction time task. Again, it seemed that muscular tension allowed the brain to work faster. Ironically, muscular tension did not affect movement time. Davranche et al. (2006) also concluded that exercise improved reaction time by increasing arousal.

Fatigue Yeung et al. (1999) thoght that fatigue could affect both force generating capacities and temporal characteristics of the neuromuscular mechanism, as fatigue could be determined by reduction of performance after continuous workload accompanied by subjective experience of exhaustion (Watanabe, Kato, & Kato, 2002). According to their result of the study, the intact total reaction time following fatigue related to the low level of fatigue. Sleep deprivation seems to affect the simple and 2-choice reaction times on resting conditions whereas not to affect them on submaximal exercise conditions (Scott et al., 2006). The study among middle aged individuals measuring the relationship between diurnal reaction time and the nocturnal slow-wave sleep showed that slow wave sleep measures were not predictive of performance on the simple reaction time both in the normal sleepers and insomnia sufferers (Edinger et al., 2000).

Welford (1980) found that reaction time gets slower when the subject is fatigued. Mental fatigue, especially sleepiness, has the greatest effect. Philip et al. (2004) found that 24 hours of sleep deprivation lengthened the reaction times of 20-25 years old subjects, but had no effect on the reaction times of 52-63 years old subjects. Van den Berg and Neely (2006) found that sleep deprivation caused subjects to have slower reaction times and to miss stimuli over a test period that lasted two hours. Takahashi et al. (2004) studied workers who were allowed to take a short nap on the job, and found that although the workers thought the nap had improved their alertness, there was no effect on choice reaction time.

Nutrition Research is equivocal as to whether nutrition quickens or delays visual reaction time. However, in a study conducted by Basgoze et al. (1989), subjects who ate breakfast prior to testing had a quicker visual reaction time than those who did not eat. Although within the subject group, those who ingested a large breakfast had a slower reaction time than those who only drank coffee. In addition, three days without food does not decrease reaction time, although it does impair capacity to do work (Gutierrez et al., 2001).

Caffeine Caffeine has often been studied in connection with reaction time. Energy drinks containing caffeine, glucuronolactone, and taurine such as Red Bull

Energy Drink cause significant reduction in choice reaction time (Alford et al., 2001). Caffeine improves cognitive task performance meaning that decreases reaction times even there is motor fatigue (Duinen et al., 2005). Kruk, Chmura, Krzeminski, Ziemba, Nazar, Pekkarinen and Kaciuba-Uscilko (2001) noted that, upon their results, caffeine stimulates the body depending on the level and source of arousal and they stated that caffeine intake decreased the choice reaction time during exercise performed in a thermoneutral environment, but not at low temperature. Of course, the familiarity to the caffeine is another subject to deserve taking attention (Jacobson and Thurmanlacey, 1992). Jacobson and Thurmanlacey (1992) found that caffeine had detrimental effects on performance skills of caffeine-naive women but not in caffeine-familiar women. Liguori et al. (2001) found that caffeine can reduce the slowing effect of alcohol on reaction time, but can't prevent other effects such as body sway.

Energy Intake Another effect having positive effect on cognitive performance is the creatine supplementation (Rae, Digney, McEwan, & Bates, 2003; Watanabe, Kato, & Kato, 2002). Another study that showed high-energy intake causes improvement reaction time was performed by Ainslie et al. (2003) in the condition that high and low energy intake groups. They found improvement in one- and two-finger reaction time, which is defined as perception task indicator in their study, in high-energy intake group whereas they could not find any change in choice reaction time (4 and 8 finger) for both groups (Ainslie et al., 2003).

Alcohol Alcohol intake also affects the reaction time in the sense that study results of Hernandez et al. (2005), which is that moderate rising blood alcohol concentrations can impair visual and auditory premotor reaction time without affecting motor reaction time. This result may suggest that social drinkers may have cognitive impairment that could slow responses and harm performance, even though motor reactions remain unaffected (Hernandez et al., 2005). Kruisselbrink et al. (2006) found that adult females who drank from one to six cans of beer did not suffer delayed reaction times the next morning, although they made more errors on a choice reaction time task. Fillmore and Blackburn (2002) found that subjects who had drunk an impairing dose of alcohol reacted faster when they were warned that this was enough alcohol to slow their reaction time. Unwarned subjects who drank suffered more decreased reaction times. However, the warned subjects were also less inhibited and careful in their responses. Even subjects who drank some nonalcoholic beverage and then were warned (falsely) about impairment by alcohol reacted faster than unwarned subjects who drank the same beverage.

Injuries Kujala and Taimela (1992) conducted a study, which suggested that musculoskeletal injuries could delay visual reaction time thus concluding that injuries can negatively affect overall reaction time. Collins et al. (2003) found that high school athletes with concussions and headache a week after injury had worse performance on reaction time and memory tests than athletes with concussions but no headache a week after injury.

Type of Stimulus Visual reaction time is also affected by the type of stimulus presented. A simple stimulus requires less cerebral processing, thus it can result in quicker reaction time than more complex stimuli. In addition, the intensity, duration, and magnitude in which a stimulus is presented may also affect how quickly an individual can process the movement command, the last phase of reaction time processing (Durst et al., 1989).

Direct vs. Peripheral Vision Brebner and Welford (1980) cite literature that shows that visual stimuli perceived by different portions of the eye produce different reaction times. The fastest reaction time comes when a stimulus is seen by the cones (when the person is looking right at the stimulus). If the stimulus is picked up by rods (around the edge of the eye), the reaction is slower. Ando et al., 2002 found that practice on a visual stimulus in central vision shortened the reaction time to a stimulus in peripheral vision, and vice versa.

Practice and Errors Sanders (1998) cited studies showing that when subjects are new to a reaction time task, their reaction times are less consistent than when they've had an adequate amount of practice. Also, if a subject makes an error (like pressing the spacebar before the stimulus is presented), subsequent reaction times are slower, as if the subject is being more cautious. Ando et al. (2002) found that reaction time to a visual stimulus decreased with three weeks of practice, and the same research team (2004) reported that the effects of practice last for at least three weeks. Fontani et al. (2006) showed that in karate, more experienced practitioners had shorter reaction times, but in volleyball, the inexperienced players had shorter reaction times (and made more errors too). Rogers et al. (2003) found that training older people to resist falls by stepping out to stabilize themselves improved their reaction time.

Warnings of Impending Stimuli Brebner and Welford (1980) report that reaction times are faster when the subject has been warned that a stimulus will arrive soon. In the reaction time program, the delay is never more than about 3 sec., but these authors report that even giving 5 minutes of warning helps. Bertelson (1967) found that as long as the warning was longer than about 0.2 sec., the shorter the warning was, the faster reaction time was. However, Perruchet et al. (2006) said that when two events are associated with one another, conscious expectation of the second event may actually slow reaction to it. They considered this evidence that expectation of an event and reaction to it are independent processes.

Order of Presentation Welford (1980), and Sanders (1998) observed that when there are several types of stimuli, reaction time will be faster where there is a 'run' of several identical stimuli than when the different types of stimuli appear in mixed order. This is called the "sequential effect." Hsieh (2002) found that the shifting of attention between two different types of tasks caused an increase in reaction time to both tasks.

Personality Type Brebner (1980) found that extroverted personality types had faster reaction times, and Welford (1980) said that anxious personality types had faster reaction times. Lenzenweger (2001) found that the reaction times of schizophrenics was slower than those of normal people, but their error rates were the same. Robinson and Tamir (2005) found that neurotic college students had more variable reaction times than their more stable peers.

Intelligence The tenuous link between intelligence and reaction time is reviewed in Deary et al. (2001). Serious mental retardation produces slower and more variable reaction times. Among people of normal intelligence, there is a slight tendency for more intelligent people to have faster reaction times, but there is much variation between people of similar intelligence (Nettelbeck, 1980). The speed advantage of more intelligent people is greatest on tests requiring complex responses (Schweitzer, 2001).

Illness Minor upper respiratory tract infections slow reaction time, make mood more negative, and cause disturbance of sleep (Smith et al., 2004).

Other Factors Ishijima, Hirai, Koshino, Konishi and Yokoyama (1998), measured reaction time on subjects with and without occlusal support jumping vertically, following a light signal while standing on a force plate. According to the results of their study, reaction time was significantly prolonged when the subjects lost their occlusal support. The study of Bender, Resch, Weisbrod and Oelkers-Ax (2004) provides important contribution to the idea that time-course of preparation processes in response to a warning stimulus since their result could elucidate there is already specific motor cortex activation early after the warning stimulus which can not be explained by the preparation immediately preceding the imperative stimulus or subsequent movement execution. According to the study of Günendi, Taşkıran, and Beyazova (2005), reaction time values decrease with repetition, but before 15 test trials, 10 practice trials are needed for learning in simple electromyographic reaction time. The colour of the signals in reaction time devices might have an effect on the reaction times. Probably because of the limitation of the device, Reinberg, Bicakova-Rocher, Mechkouri and Ashkenazi (2002) used colours just as in the traffic, that is that, yellow signal for single reaction times, and randomized yellow, red or green signal for choice reaction times. However, in the present study, the orange colour was used for all the reaction time measurements in order to avoid confusing effect because of the colour of traffic lights.

2.1.9. Driving ability

Driving is the activity that requires fast responding (Silverman, 2006). On-road driving performance and reaction time moderately correlated with larger associations being found for complex reaction time than simple reaction time (McKnight et. al., 1999). Their sample size was 407 drivers aged 62 and above. In the study of Cnossen, Meijman and Rothengatter (2004) who investigated adaptive strategy changes on car drivers, mean annual kilometres driven were 19000. Nevertheless, mean yearly driving distance was taken as 12,225 ± 4739 km in the study made with twenty-two healthy male subjects considering the issue that the effect of fatigue and sleep restriction on driving performance (Philip et al., 2005). Beside, Sung, Min, Kim and Kim (2005) had taken the period of driving experience as 4.1 ± 1.2 years in their study measuring the effect of oxygen concentrations on fatigue during simulated driving with the mean ages of subjects 24.1 ± 2.4 years. Generally, mean annual kilometers were the base line in the previous studies. However, life-time driving experience as kilometers could be a criteria for the definition of drivers. More than 250 000 km life-time driving experience with no self-reported crashes was required to count a driver, aged between 40 and 50, in measuring the performance of drivers with impairment to their central field of vision in the study of Lamble, Summala and Hyvarinen (2002).

There are some factors that correlate with driving ability such as use of a hands-free cellular phone (Lin & Chen, 2006), severity of physical disease (Hardy et al., 2002; Singh, Pentland, Hunter, & Provan, 2007), age, presence of other associated medical conditions, duration of disease, brake reaction, time on a test rig and score on a driving test (Singh et al., 2007). Most important factors among them were severe physical disease, reaction time, moderate disease associated with another medical condition and high score on car testing (Singh et al., 2007). Also, there are some studies showing the effect of assorted effects on reaction times. For example, simple and complex reaction times are not affected by smokeless tobacco use or abstention (Escher et al., 1998), in healthy individuals, reaction time is not affected by up to 30 days of moderate undernutrition (ShukittHale et al., 1997), using hands-free cellular phones affects reaction time while driving (Lin et al., 2006).

CHAPTER 3

METHOD

3.1. Subjects

The total number of participants was 120 (of which 60 were males and 60 were females). They were chosen to be divided into 3 groups as driver, exercise and control groups. Each of these groups contains 20 males and 20 females. The mean age of whole participants was 25.62 years whereas the control group mean age was 24.93 years, exercise group mean age was 25.3 years and the driver group mean age was 26.63 years. Before taking part in the experiment, all participants read and signed informed consents and information forms and were debriefed about the protocol of the study (see Appendix A).

The driver group composed of the drivers who have mean annual kilometers of at least 20.000 km and drive for at least 5 years. But the exclusion criterion for the use of vehicle was less than 15000 km. The exercise group was expected to doing regular exercise for at least three years, three days in a week and two hours in an exercise day. Also, a requirement about the exercise type was that the sport must include visual reactive movements namely taekwondo. However, the control group was expected to be in the exclusion criteria and not to do regular exercise. Control and sport group had some participants who had driving licence and were driving a car with an annual distance of less than 15.000 km. per year.

3.2. Materials

Reaction time device A portable reaction time device (Sport Expert MPS-501, Tümer Engineering, CO.) was used to assess the reaction times. The device had three parts which are that a) central unit having LCD display screen, b) stimulus generator and c) junction box. Stimulus generator had visual apparatus, and junction box had Piezo switches. The subject pressed the switch when he/she sees the light, and so the central unit gives the duration between the subject's seeing the light and pressing the switch. It was noted as reaction time of that measurement in seconds. Simple visual reaction time, simple visual reaction time with and without movement times, two & three visual choices reaction times were taken for both hands 3 times (24 times total at all) in each subject in the experiment. The data of the subjects, which include the information that name, dominant hand, the time and day of his/her measurement, and caffeine intake situation for last three hours were recorded on a sheet (See Appendix B).

3.3. Design

The design of the study was cross-sectional one-shot case experimental study (see table 1). The independent variables were sex (male and female) and groups (control, driver and exercise) whereas the dependent variable was reaction times. The dependent variables were simple visual reaction time, simple visual reaction time with movement times, two choice visual reaction time and three choice visual reaction time (Table 1). There are also control variables such as age interval, which was between 18 and 35, measurement time which was during the working hours of the day, no caffeine intake, and test which begins one subject with dominant hand and the other with non-dominant hand.

Table 1. Measurement scale

Variables	SIMPLE RT				CHOICE RT			
	Visual RT		Visual RT with MT		Two-Choice RT		Three-Choice RT	
GROUPS Female/Male	Right 1 2 3	Left 1 2 3	Right 1 2 3	Left 1 2 3	Right 1 2 3	Left 1 2 3	Right 1 2 3	Left 1 2 3
Control 1 . 20								
Exercise 1 . 20								
Driver 1 . 20								

3.4. Procedure

Researcher made a preliminary data collection in order to be familiar with the device and the procedure. It was run with 10 participants who were not included in the main data collection procedure. In main data collection procedure, measurements were taken orderly as in the measurement scale (Table 1, Appendix C). Participants who were volunteered were randomly allocated in each sex, considering their hand dominance. In order to eliminate the training effect, the half of participants of each group were initiated with dominant hand and the other half of them were initiated with non-dominant hand. Every measurement category had three measurements for both hands. Participants were asked to react to each visual stimulus by pushing the switch as fast as they could. After signing informed consent, experiment was begin for every participant in the same way. Before each measurement, the researcher gave the command 'ready'. After the command, the subject presses the switch that causes a sound afterwards. First, a trial for simple visual reaction time measurement was demonstrated by the researcher and then, the subject tried. After that, the actual measurements were taken beginning with visual reaction time. Consecutively, simple visual reaction time with movement was measured with the same procedures. For simple visual reaction time measurements, the participants were requested to hold his/her sign finger on the Piezo switch. After the simple visual reaction time measurement, the subject was requested to hold his/her sign finger 2 cm. below the switch to measure simple visual reaction time with movement time (Figure 2). When this measurement was completed, the choice reaction time measurements were begun. First two-choice and then three-choice visual reaction time measurements were taken with the same procedures (Figure 3). It was anticipated especially in the drivers, there is stimulus-response compatibility. For the visual signals, the orange arrow shape was used since other two colors which is green and red may cause a familiarize because of traffic lamps. For simple visual signal, right arrow shape was used, for two-choice visual signal, right and left arrow shapes were used and finally, for three-choice visual signal, right, left and up arrow shapes were used.

Figure 2. Experiment Setup for Simple Visual Reaction Time and Simple Visual Reaction Time with Movement

Figure 3. Experiment Setup for Two Choice Reaction Time and Three Choice Reaction Time

3.5. Statistical analysis

In total, there are four dependent variables and two independent variables. Hence, two-way factorial MANOVA was used as the statistical analysis for the group difference. In order to determine which variable caused significant effect, a separate analysis (mean difference) was done for the follow-up test. For MANOVA analysis, the significance level was set as α =0.05. But, for the computed ANOVA and Post-Hoc analysis ensuing the MANOVA analysis, α =0.05 was divided into the number of dependent variables via using Bonferroni technique, and for these two analysis, α =0.05 / 4 = 0.0125 was found.

Both standard deviation and standard error values were used. For the descriptive statistics, standard deviation was used whereas standard error was used for the statistical analyses. For interaction, all interpretations were done under the light of means and standard deviations.

One sample t-test was used for the comparison of simple and choice reaction times. And, a separate MANOVA was computed for the four dependent variables for the hand dominance.

CHAPTER 4

RESULTS

The purpose of the study was to investigate sex and group differences in reaction times of exercise, drivers and control groups for both right and left hands. A two-way (2x3) multivariate analysis of variance (MANOVA) was performed. Moreover, the right and left hands results were separately computed. Four dependent variables were used: simple visual reaction time, simple visual reaction time with movement, two and three choice reaction times. The independent variables were sex, groups, and hand dominance. The statistical analyses were performed using SPSS software.

The mean age of control female (CF) group was $M = 24.35$, that of exercise female (EF) group was $M = 24.85$, that of driver female (DF) group was $M = 25.75$ (Table 2). The mean ages of female groups were similar with those of male groups. The mean age of control male (CM) group was $M = 25.5$, that of exercise male (EM) group was $M = 25.75$, that of driver male (DM) group was $M = 27.5$. The driver female group ($M = 44.750$) was clearly distinguished from driver male group ($M = 56.500$) in mean annual kilometers. Both female and male exercise group had scores that is convenient to inclusion and exclusion criteria. They have sport experience more than 6 years (for females $M = 6.3$, for males $M = 6.55$). At the same time, they had at least 3 training days in a week (for females $M = 3.4$, for males. $M = 3.45$), and more than 2 hours in one training day (for females $M = 2.45$, for males $M = 2.5$) (Table 2). In male exercise group, the majority of subjects had more than 5 years experience except one participant who had 4 years experience.

For the simple reaction times, means and standard deviations of groups were showed in Table 3.

Table 2. Means and standard deviations of group demographic values

Groups N = 20	Age		D. Hand		*M* Annual (km.)		Days		Hours		Years	
	M	*SD*	R (N)	L (N)	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
CF	24.35	3.91	15	5	-	-	-	-	-	-	-	-
CM	25.5	4.22	13	7	-	-	-	-	-	-	-	-
EF	24.85	4.33	15	5	-	-	3.4	0.5	2.45	.51	6.3	1.84
EM	25.75	3.68	14	6	-	-	3.45	0.51	2.5	.51	6.55	1.67
DF	25.75	3.86	17	3	44.750	10.320	-	-	-	-	-	-
DM	27.5	3.69	15	5	56.500	11.250	-	-	-	-	-	-

Note: CF: Control female, CM: Control male, EF: Exercise female, EM: Exercise male, DF: Driver female, DM: Driver male, R: Right hand, L: Left hand, *M*: Mean, *SD*: Standard deviation, N: Number, D. Hand: Dominant hand, km: kilometers.

In simple visual reaction time, the shortest reaction time score is driver group's female participants (*M* = 0.29, *SD* = 0.2) for the right hand. After that score, the score of female participants in exercise group (*M* = 0.30, *SD* = 0.3), then male participants in exercise group (*M* = 0.32, *SD* = 0.3), then male participants in driver group (*M* = 0.33, *SD* = 0.4), then female participants in control group (*M* = 0.35, *SD* = 0.4), and then male participants in control group (*M* = 0.40, *SD* = 0.4) followed. Beside, for the left hand, sequence of scores is different from that of right hand. The shortest simple visual reaction time score for the left hand is both exercise group's female (*M* = 0.29, *SD* = 0.2) and driver group's female (*M* = 0.29, *SD* = 0.1) participants'. Exercise and driver group's male participants followed them with similar scores (for the exercise group's male participants, *M* = 0.31, *SD* = 0.4, for the driver group's male participants, *M* = 0.31, *SD* = 0.3) for the left hand in simple visual reaction time. Finally, control male participants (*M* = 0.35, *SD* = 0.3) had shorter scores than control female participants (*M* = 0.40, *SD* = 0.3) for the left hand in simple visual reaction time. Driver group's female participants had shortest score (*M* = 0.35, *SD* = 0.2) for the right hand in simple visual reaction time with movement. After this shortest score, the closest score is two groups' which are that male participants in exercise group (*M* = 0.36, *SD* = 0.4) and male participants in driver group (*M* = 0.36, *SD* = 0.3). Exercise group's female participants (*M* = 0.39, *SD* = 0.4) had smaller score than control group's both male (*M* = 0.41, *SD* = 0.4) and female (*M* = 0.46, *SD* = 0.4) participants for the right hand in simple visual reaction time with movement. For the left hand in simple visual reaction time with movement, three similar scores were the shortest, and they are exercise group's male participants' (*M* = 0.36, *SD* = 0.4), driver group's female (*M* = 0.36, *SD* = 0.2) and male (*M* = 0.36, *SD* = 0.3) participants. Exercise group's female participants (*M* = 0.40, *SD* = 0.2) had shorter score than control group's male (*M* = 0.41, *SD* = 0.3) and female (*M* = 0.47, *SD* = 0.3) participants' for the left hand in simple visual reaction time with movement.

Table 3. Means and standard deviations of groups in simple reaction time

Group	Simple Reaction Time							
	Visual				Visual-Mt			
	R		L		R		L	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
CF	.35	.04	.40	.03	.46	.04	.47	.03
CM	.40	.04	.35	.03	.41	.04	.41	.03
EF	.30	.03	.29	.02	.39	.04	.40	.02
EM	.32	.03	.31	.04	.36	.04	.36	.04
DF	.29	.02	.29	.01	.35	.02	.36	.02
DM	.33	.04	.31	.03	.36	.03	.36	.03

Note: CF: Control female, CM: Control male, EF: Exercise female, EM: Exercise male, DF: Driver female, DM: Driver male, R: Right hand, L: Left hand, *M*: Mean, *SD*: Standard deviation.

For the choice reaction times, means and standard deviations of groups were showed in Table 4. The shortest reaction time score is male participants' in driver group both for the right (*M* = 0.48, *SD* = 0.7) and left (*M* = 0.48, *SD* = 0.5) hand in two choice reaction time. Female participants in exercise group (*M* = 0.49, *SD* = 0.6) follow with the second shortest score. Other participants had scores in the order that female participants in driver group (*M* = 0.50, *SD* = 0.4), male participants in exercise group (*M* = 0.51, *SD* = 0.4), male participants in control group (*M* = 0.53, *SD* = 0.3), and female participants in control group (*M* = 0.58, *SD* = 0.4) for the right hand in two choice reaction time. However, for the left hand, the second shortest reaction time score is both exercise (*M* = 0.49, *SD* = 0.4) and driver (*M* = 0.49, *SD* = 0.4) group's female participants'. After those scores, exercise group's male participants (*M* = 0.53, *SD* = 0.2) had smaller value than control group's male (*M* =

0.54, *SD* = 0.4) and female (*M* = 0.59, *SD* = 0.3) participants. In three choice reaction time, the shortest reaction time score is exercise group's male participants' (*M* = 0.51, *SD* = 0.3), after that, the female participants' (*M* = 0.55, *SD* = 0.4) for the right hand. The driver group followed the exercise group similar for both female (*M* = 0.56, *SD* = 0.5) and male (*M* = 0.56, *SD* = 0.6) participants. Finally, the control group followed them with the shorter score for male participants (*M* = 0.59, *SD* = 0.6) than female participants (*M* = 0.65, *SD* = 0.4) for the right hand in three choice reaction time. The order of scores for left hand in three choice reaction time is similar in groups. The shortest reaction time scores is exercise group's (for male participants (*M* = 0.52, *SD* = 0.3), for female participants (*M* = 0.53, *SD* = 0.2), secondly driver group's (for male participants (*M* = 0.56, *SD* = 0.5) , for female participants (*M* = 0.56, *SD* = 0.5), and then control group's (for male participants (*M* = 0.60, *SD* = 0.5), for female participants (*M* = 0.64, *SD* = 0.5).

Table 4. Means and standard deviations of groups in choice reaction time

Group	Choice Reaction Time							
	Two				Three			
	R		L		R		L	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
CF	.58	.04	.59	.03	.65	.04	.64	.05
CM	.53	.03	.54	.04	.59	.06	.60	.05
EF	.49	.06	.49	.04	.55	.04	.53	.02
EM	.51	.04	.53	.02	.51	.03	.52	.03
DF	.50	.04	.49	.04	.56	.05	.56	.05
DM	.48	.07	.48	.05	.56	.06	.56	.05

Note: CF: Control female, CM: Control male, EF: Exercise female, EM: Exercise male, DF: Driver female, DM: Driver male, R: Right hand, L: Left hand, *M*: Mean, *SD*: Standard deviation.

4.1. Statistical analysis for the interaction between sex and group

4.1.1. Results for the right hand

Preliminary assumption testing for right hand analysis was conducted to check for normality, linearity, univariate and multivariate outliers, homogeneity of variance-covariance matrices, and multicollinearity, with no serious violations noted. Results of the analysis for the right hand revealed (see table 5) that there was a statistically significant interaction between the sex and group, Wilks' Lambda=.66,

$F_{(222,8)}$= 6.27, p <.05, and $\eta = .18$ which is a large effect according to Cohen (Pallant, 2001).

Since significant interaction was found between sex and group, the result of the test of between-subjects effects (ANOVA) was checked in order to find in which dependent variable there was a significant interaction. Results of the ANOVA revealed (see table 6) significant interaction for simple visual reaction time (SVRT) $F_{(2,114)}$= 12.11, p <.01, and $\eta = .17$ which is a large effect, and simple visual reaction time with movement (SVRT-M) $F_{(2,114)}$= 6.05, p <.01, and $\eta = .10$ which is a moderate effect. Significant interactions were not found for the two choice reaction

Table 5. 2 (Sex) x 3 (Groups) MANOVA Results for the Interaction between Sex and Group for Right Hand

Effect	Value	*F*	Hypothesis *df*	Error *df*	*p*	*η*
Sex	.843	5.168	4	111	.001*	.157
Group	.386	16.892	8	222	.001*	.378
Sex * Group	.665	6.275	8	222	.001*	.184

* $p < 0.05$

time (TCRT) $F_{(2,114)}$= 4.59, p >.01, and $\eta = .07$ which is a moderate effect and three choice reaction time (ThrCRT) $F_{(2,114)}$= 2.82, p >.01, and $\eta = .04$ which is a small effect. Because significant interactions were found between sex and group for three dependent variables, Post-Hoc analyses were not conducted.

Table 6. Results of the ANOVA for Sex, Group and Sex x Group for Right Hand

Source	Dependent Variable	*df*	Mean Square	*F*	*p*	*η*
Sex	SVRT (Min)	1	.000	.247	.620	.002
	SVRT-M (Min)	1	.014	9.129	.003	.074
	TCRT (Min)	1	.012	4.516	.036	.038
	ThrCRT (Min)	1	.029	11.691	.001	.093
Group	SVRT (Min)	2	.062	45.477	.001	.444
	SVRT-M (Min)	2	.068	44.076	.001	.436
	TCRT (Min)	2	.044	16.398	.001	.223
	ThrCRT (Min)	2	.086	34.399	.001	.376
Sex * Group	SVRT (Min)	2	.017	12.113	.001	.175
	SVRT-M (Min)	2	.009	6.055	.003	.096
	TCRT (Min)	2	.013	4.592	.012	.075
	ThrCRT (Min)	2	.007	2.820	.064	.047
Error	SVRT (Min)	114	.001			
	SVRT-M (Min)	114	.002			
	TCRT (Min)	114	.003			
	ThrCRT (Min)	114	.002			

Note: SVRT: Simple Visual Reaction Time, SVRT-M: Simple Visual Reaction Time with movement, TCRT: Two Choice Reaction Time, ThrCRT: Three Choice Reaction Time

Interactions for SVRT, and SVRT-M were shown in figure 4, and 5. In the figure 4, which shows the interaction between the sex and group on simple visual reaction time, the highest reaction time score belongs to the females in control group (*M* = 0.40, *SD* = 0.04) whereas the lowest reaction time score belongs to females in driver group (*M* = 0.29, *SD* = 0.02). While the score of male participants (*M* = 0.35, *SD* = 0.04) in control group was lower than that of female participants (*M* = 0.40, *SD* = 0.04) in the same group, both exercise and driver group have lower scores in females (for exercise group *M* = 0.30, *SD* = 0.03, for driver group *M* = 0.29, *SD* = 0.02) than males (for exercise group *M* = 0.32, *SD* = 0.03, for driver group *M* = 0.31, *SD* = 0.02). The sex difference in mean reaction time scores among groups was the biggest in control group. The mean scores of female exercise (*M* = 0.30, *SD* = 0.03) and female driver (*M* = 0.29, *SD* = 0.02) groups were similar and it is so for male exercise (*M* = 0.32, *SD* = 0.03) and male driver (*M* = 0.31, *SD* = 0.02) groups. The differences on reaction time scores between female participants who are in control group and in exercise and driver groups are higher than the differences between male participants who are in control group and in exercise and driver groups.

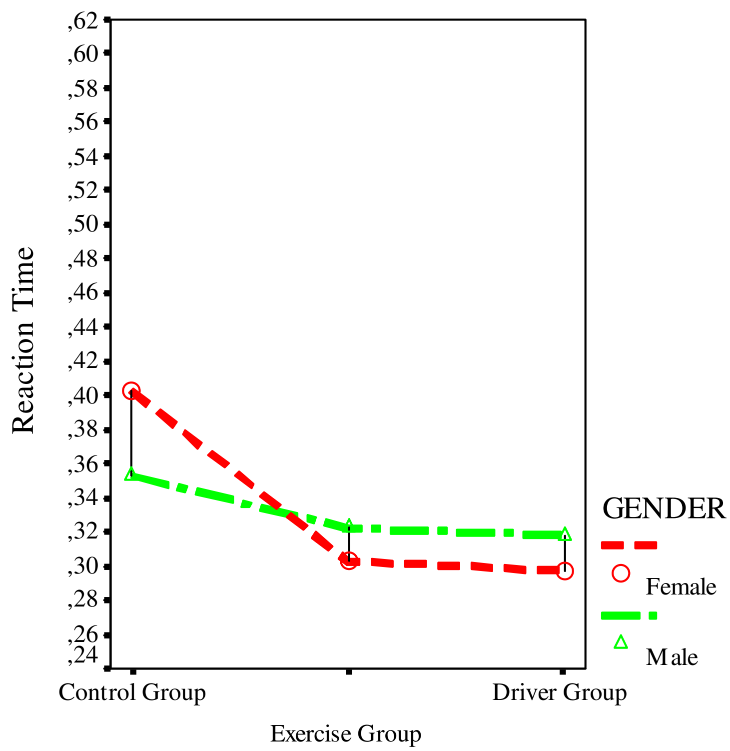

Figure 4. Plot of Means for Simple Visual Reaction Time for Right Hand

In the figure 5, which shows the interaction between the sex and group on simple visual reaction time with movement, it can be seen that the lowest reaction time mean score belongs to female participants (*M* = 0.35, *SD* = 0.02) in driver group, while the control group's female participants (*M* = 0.47, *SD* = 0.04) have the highest. In driver group, the female and male participants' mean scores were closest (for female *M* = 0.35, *SD* = 0.02, for male *M* = 0.36, *SD* = 0.03) among the mean scores of female and male participants in control (for female *M* = 0.47, *SD* = 0.04, for male *M* = 0.41, *SD* = 0.04) and exercise (for female *M* = 0.39, *SD* = 0.04, for male *M* =

0.36, *SD* = 0.04) groups. The mean score of male participants in exercise group (*M* = 0.36, *SD* = 0.04) was alike that of male participants in driver group (*M* = 0.36, *SD* = 0.03). This situation is not consistent for females in exercise and driver groups.

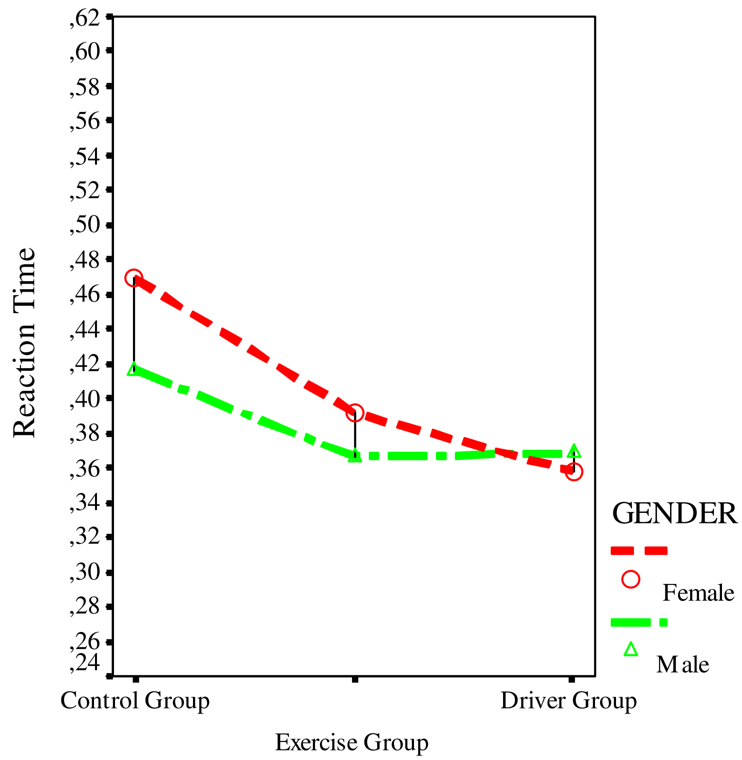

Figure 5. Plot of Means for Simple Visual Reaction Time with Movement for Right Hand

As there was no significant interaction among the two and three choice reaction times, explanation about their results is not stated.

4.1.2. Results for the left hand

Preliminary assumption testing for left hand analysis was conducted to check for normality, linearity, univariate and multivariate outliers, homogeneity of variance-covariance matrices, and multicollinearity, with no serious violations noted. Results of the analysis for the left hand revealed (table 7) that there was a statistically significant interaction between the sex and group, Wilks' Lambda=.60 $F_{(222,8)}$= 7.98, p <.05, and $\eta = .22$, which is a large effect according to Cohen (Pallant, 2001).

Since significant interaction was found between sex and group, the result of the test of between-subjects effects (ANOVA) was checked in order to find in which dependent variable there was a significant interaction. Results of the ANOVA

Table 7. 2 (Sex) x 3 (Groups) MANOVA Results for the Interaction between Sex and Group for Left Hand

Effect	Value	*F*	Hypothesis df	Error df	*p*	η
Sex	.813	6.383	4	111	.001*	.187
Group	.253	27.396	8	222	.001*	.497
Sex * Group	.603	7.986	8	222	.001*	.223

* $p < 0.05$

revealed (see table 8) significant interaction for simple visual reaction time (SVRT) $F_{(2,114)} = 13.91$, $p < .01$, and $\eta = .19$ which is a large effect, and simple visual reaction time with movement (SVRT-M) $F_{(2,114)} = 7.08$, $p < .01$, and $\eta = .11$, which is a moderate effect, and two choice reaction time (TCRT) $F_{(2,114)} = 13.78$, $p < .01$, and $\eta = .19$, which is a large effect. Significant interactions were not found for the three choice reaction time (ThrCRT) $F_{(2,114)} = 2.12$, $p > .01$, and $\eta = .03$, which is a small effect. Because significant interactions were found between sex and group for three dependent variables, Post-Hoc analyses were not conducted.

Interactions for SVRT, SVRT-M, and TCRT were shown in figure 6, 7, and 8. According to the figure 6, it can be seen that the highest reaction time mean score was that of female participants' (*M* = 0.40, *SD* = 0.03) in the control group, whereas female participants in driver group have the lowest value (*M* = 0.29, *SD* = 0.01). They had slight difference with the female participants (*M* = 0.29, *SD* = 0.02) of exercise group. Similarly, male participants in exercise (*M* = 0.31, *SD* = 0.04) and driver (*M* = 0.31, *SD* = 0.03) groups had alike mean scores of reaction time. Among male participants, the slowest reaction time belongs to the control group (*M* = 0.35, *SD* = 0.03).

Table 8. Results of the ANOVA for Sex, Group and Sex x Group for Left Hand

Source	Dependent Variable	*df*	Mean Square	*F*	*p*	*η*
Sex	SVRT (Min)	1	.002	1.674	.198	.014
	SVRT-M (Min)	1	.029	23.120	.001	.169
	TCRT (Min)	1	.002	1.345	.249	.012
	ThrCRT (Min)	1	.010	4.423	.038	.037
Group	SVRT (Min)	2	.075	67.134	.001	.541
	SVRT-M (Min)	2	.069	55.720	.001	.494
	TCRT (Min)	2	.062	37.101	.001	.394
	ThrCRT (Min)	2	.081	36.389	.001	.390
Sex * Group	SVRT (Min)	2	.016	13.914	.001	.196
	SVRT-M (Min)	2	.009	7.082	.001	.111
	TCRT (Min)	2	.023	13.781	.001	.195
	ThrCRT (Min)	2	.005	2.121	.125	.036
Error	SVRT (Min)	114	.001			
	SVRT-M (Min)	114	.001			
	TCRT (Min)	114	.002			
	ThrCRT (Min)	114	.002			

Note: SVRT: Simple Visual Reaction Time, SVRT-M: Simple Visual Reaction Time with movement, TCRT: Two Choice Reaction Time, ThrCRT: Three Choice Reaction Time

From the figure 7, female participants (*M* = 0.46, *SD* = 0.04) in control group were seen as the slowest. The male participants (*M* = 0.41, *SD* = 0.03) in control group follow them with the second slowest values. The exercise group's males (*M* = 0.36, *SD* = 0.04) had very slightly lower mean scores than driver group's females (*M* = 0.36, *SD* = 0.02) and males (*M* = 0.36, *SD* = 0.03). The difference between the male and female reaction time mean scores in control group (for female *M* = 0.46,

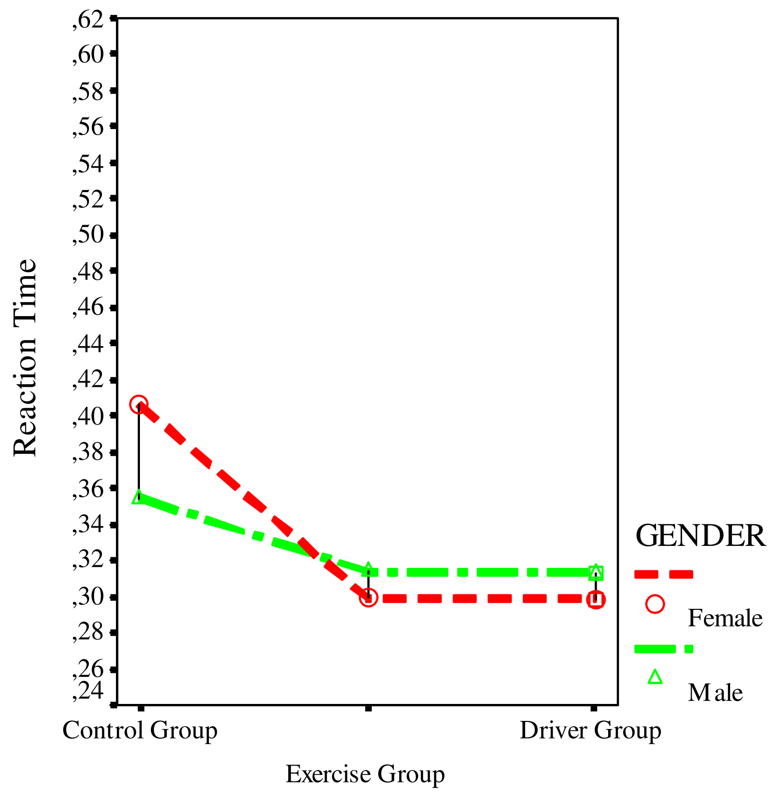

Figure 6. Plot of Means for Simple Visual Reaction Time for Left Hand

SD = 0.04, for male *M* = 0.41, *SD* = 0.03) was bigger than both the differences between the male and female mean scores in exercise group (for female *M* = 0.40, *SD* = 0.02, for male *M* = 0.36, *SD* = 0.04) and driver group (for female *M* = 0.36, *SD* = 0.02, for male *M* = 0.36, *SD* = 0.03).

According to figure 8, again the highest value belongs to the control group's females (*M* = 0.59, *SD* = 0.03) whereas the lowest value belongs to the driver group's males (*M* = 0.48, *SD* = 0.05). The mean scores of females in exercise group (*M* = 0.49, *SD* = 0.04) and males in driver group (*M* = 0.48, *SD* = 0.05) were close to the lowest value among the groups. There is very slight difference between the exercise (*M* = 0.49, *SD* = 0.04) and driver (*M* = 0.49, *SD* = 0.04) group's female participants while there is a big difference between the exercise (*M* = 0.53, *SD* = 0.02) and driver (*M* = 0.48, *SD* = 0.05) group's male participants. The mean scores of

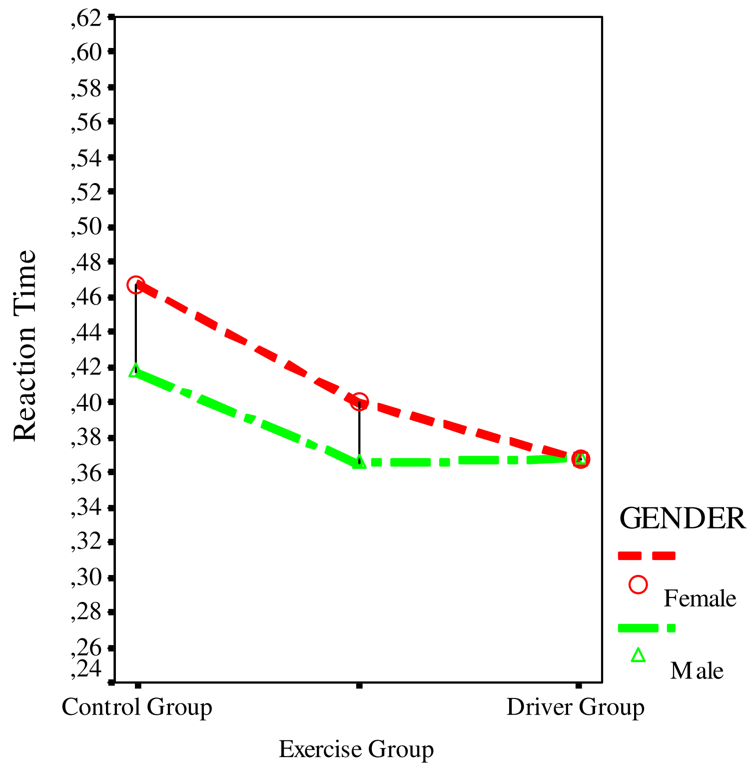

Figure 7. Plot of Means for Simple Visual Reaction Time with Movement for Left Hand

control (*M* = 0.54, *SD* = 0.03) and exercise (*M* = 0.53, *SD* = 0.02) group were close for male participants.

As there was no significant interaction among the simple auditory and three choice reaction times, explanation about their results is not stated.

4.2. Statistical analysis for the sex differences

4.2.1. Results for the right hand

Another aim of this study was to compare reaction time scores of male and female participants between two sexs. According to the result of factorial MANOVA significant main effect was found on dependent variables between sex, Wilks' Lambda=.84, $F_{(4,111)}$= 5.16, p <.05. and η = .15, which is a large effect (see Table 5). Since significant main effect was found among sex, ANOVA analysis was conducted to find in which dependent variables there is a significant difference. Results of the ANOVA revealed (see table 6) significant main effect for simple visual reaction time

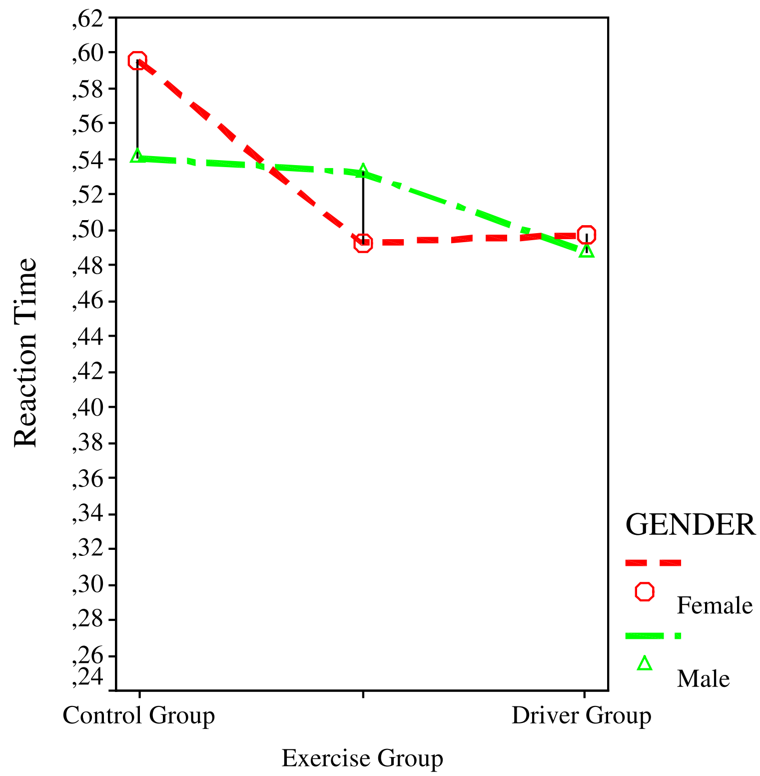

Figure 8. Plot of Means for Two Choice Reaction Time for Left Hand

with movement (SVRT-M) $F_{(1,114)}$= 9.13, p <.01, and η = .07 which is a moderate effect, and three choice reaction time (ThrCRT) $F_{(1,114)}$= 11.69, p <.01, and η = .09, which is a moderate effect. There was no significant main effect for simple visual reaction time (SVRT) $F_{(1,114)}$= 0.24, p >.01, and η = .00 which is a small effect, and for two choice reaction time (TCRT) $F_{(1,114)}$= 4.51, p >.01, and η = .03 which is a moderate effect.

For the simple visual reaction time, female groups (M = 0.33, SE = 0.005) have similar reaction time score with male groups (M = 0.33, SE = 0.005), (see Table 9). For the simple reaction time with movement score, male groups (M = 0.38, SE = 0.005) have significantly shorter score than female groups (M = 0.40, SE = 0.005). For the two choice reaction time, the score of females (M = 0.52, SE = 0.007) is higher than that of males (M = 0.51, SE = 0.007). For the three choice reaction time score, the score of male groups (M = 0.56, SE = 0.007) is significantly shorter than female groups (M = 0.58, SE = 0.007).

Table 9. Means, Standard Deviations, and Standard Errors of the Female and Male Participant Scores for Right Hand

Dependent Variables	Sex	*M*	*SD*	*SE*
SVRT	Female	.334	.060	.005
	Male	.331	.040	.005
SVRT-M	Female	.406	.061	.005
	Male	.384	.044	.005
TCRT	Female	.528	.064	.007
	Male	.510	.056	.007
ThrCRT	Female	.587	.065	.007
	Male	.559	.061	.007

Note: SVRT: Simple Visual Reaction Time, SVRT-M: Simple Visual Reaction Time with movement, TCRT: Two Choice Reaction Time, ThrCRT: Three Choice Reaction Time

4.2.2. Results for the left hand

Another aim of this study was to compare reaction time scores of participants between sexes. According to the result of factorial MANOVA significant main effect was found on dependent variables between sex, Wilks' Lambda=.81, $F_{(4,111)}$= 6.38, p <.05. and η = .18, which is a large effect (see Table 7). Since significant main effect was found among sexes, ANOVA analysis was conducted to find in which dependent variables there is a significant difference. Results of the ANOVA revealed (see table 8) significant main effect for simple visual reaction time with movement (SVRT-M) $F_{(1,114)}$= 23.12, p <.01, and η = .16 which is a moderate effect. There is no significant main effect for simple visual reaction time (SVRT) $F_{(1,114)}$= 1.67, p >.01, and η = .01 which is a small effect, for two choice reaction time (TCRT) $F_{(1,114)}$= 1.34, p >.01, and η = .01 which is a small effect, and three choice reaction time (ThrCRT) $F_{(1,114)}$= 4.42, p >.01, and η = .03, which is a moderate effect.

For the simple visual reaction time, female groups (M = 0.33, SE = 0.004) have higher reaction time score than male groups (M = 0.32, SE = 0.004), (see Table 10). For the simple reaction time with movement score, male groups (M = 0.38, SE = 0.005) have significantly shorter score than female groups (M = 0.41, SE = 0.005).

For the two choice reaction time, the score of females (*M* = 0.53, *SE* = 0.005) is higher than that of males (*M* = 0.52, *SE* = 0.005). For the three choice reaction time score, the reaction time score of male groups (*M* = 0.56, *SE* = 0.006) is significantly shorter than female groups (*M* = 0.57, *SE* = 0.006).

Table 10. Means, Standard Deviations, and Standard Errors of the Female and Male Participant Scores for Left Hand

Dependent Variables	Sex	*M*	*SD*	*SE*
SVRT	Female	.334	.057	.004
	Male	.327	.042	.004
SVRT-M	Female	.412	.053	.005
	Male	.383	.045	.005
TCRT	Female	.529	.061	.005
	Male	.520	.047	.005
ThrCRT	Female	.578	.063	.006
	Male	.563	.056	.006

Note: SVRT: Simple Visual Reaction Time, SVRT-M: Simple Visual Reaction Time with movement, TCRT: Two Choice Reaction Time, ThrCRT: Three Choice Reaction Time

4.3. Statistical analysis for the group differences

4.3.1. Results for the right hand

One of the aims of this study was to compare reaction time scores of participants among the groups. Therefore, besides the interaction, the main effect of the group also reported. According to the result of factorial MANOVA significant main effect was found on dependent variables among the three groups, Wilks' Lambda=.38, $F_{(8,222)}$= 16.89, p <.05, and $\eta = .37$ which is a large effect (Table 5).

Since significant main effect was found among the groups, ANOVA analysis was conducted to find in which dependent variables there was a significant difference. Results of the ANOVA revealed (see table 6) significant main effect for simple visual reaction time (SVRT) $F_{(2,114)}$= 44.85, p <.01, and $\eta = .44$ which is a large effect, simple visual reaction time with movement (SVRT-M) $F_{(2,114)}$= 44.73, p <.01, and $\eta = .44$ which is a large effect, two choice reaction time (TCRT) $F_{(2,114)}$=

13.75, p <.01, and $\eta = .19$ which is a large effect and three choice reaction time (ThrCRT) $F_{(2,114)}$= 28.64, p <.01, and $\eta = .33$ which is a large effect.

Post-Hoc analyses were conducted for each dependent variable to find the any difference between groups (see Table 11). For the simple visual reaction time, driver group (*M* = 0.30, *SE* = 0.006) has significantly smaller reaction time score than the control (*M* = 0.37, *SE* = 0.006) and exercise (*M* = 0.31, *SE* = 0.006) groups. For the simple reaction time with movement score, significantly shorter reaction time score belongs to the driver group (*M* = 0.36, *SE* = 0.006), while the control group (*M* = 0.44, *SE* = 0.006) has longer reaction time than exercise (*M* = 0.38, *SE* = 0.006) and driver groups. For the two choice reaction time, the score of control (*M* = 0.55, *SE* = 0.008) group is the highest whereas the exercise (*M* = 0.50, *SE* = 0.008) and driver (*M* = 0.50, *SE* = 0.008) groups' reaction time score is similar. For the three choice reaction time score, the reaction time score of exercise (*M* = 0.55, *SE* = 0.008) group is the shortest, among control (*M* = 0.62, *SE* = 0.008) and driver (*M* = 0.56, *SE* = 0.008) groups.

Table 11. Means, Standard Deviations, and Standard Errors of Groups According to Dependent Variables for Right Hand

Dependent Variable	Group	*M*	*SD*	*SE*
SVRT (Min)	Control Group	.378	.052	.006
	Exercise Group	.312	.034	.006
	Driver Group	.308	.029	.006
SVRT-M (Min)	Control Group	.443	.052	.006
	Exercise Group	.379	.042	.006
	Driver Group	.363	.029	.006
TCRT (Min)	Control Group	.555	.052	.008
	Exercise Group	.504	.053	.008
	Driver Group	.497	.059	.008
ThrCRT (Min)	Control Group	.621	.063	.008
	Exercise Group	.534	.040	.008
	Driver Group	.564	.056	.008

Note: SVRT: Simple Visual Reaction Time, SVRT-M: Simple Visual Reaction Time with movement, TCRT: Two Choice Reaction Time, ThrCRT: Three Choice Reaction Time

4.3.2. Results for the left hand

One of the aims of this study was to compare reaction time scores of participants among the groups. Therefore, besides the interaction, the main effect of the group was also reported. According to the result of factorial MANOVA significant main effect was found on dependent variables among the three groups. Wilks' Lambda=.25, $F_{(8,222)}$= 27.39, p <.05, and $\eta = .49$ which is a large effect (Table 7).

Since significant main effect was found among the groups, ANOVA analysis was conducted to find in which dependent variables there is a significant difference. Results of the ANOVA revealed (table 8) significant main effect for simple visual reaction time (SVRT) $F_{(2.114)}$= 67.13, p <.01, and η = .54, which is a large effect, simple visual reaction time with movement (SVRT-M) $F_{(2.114)}$= 55.72, p <.01, and $\eta = .49$, which is a large effect, two choice reaction time (TCRT) $F_{(2.114)}$= 37.10, p <.01, and $\eta = .39$, which is a large effect and three choice reaction time (ThrCRT) $F_{(2.114)}$= 36.38, p <.01, and $\eta = .39$, which is a large effect.

Post-Hoc analyses were conducted for each dependent variable to find the any difference between groups (see Table 12). For the simple visual reaction time, control group (M = 0.38, SE = 0.005) has significantly higher reaction time score than other groups where the scores of exercise (M = 0.30, SE = 0.005) and driver (M = 0.30, SE = 0.005) groups were similar. For the simple reaction time with movement score, significantly shorter reaction time score belongs to the driver group (M = 0.36, SE = 0.006), while the control group (M = 0.44, SE = 0.006) has longer reaction time than exercise (M = 0.38, SE = 0.006) and driver groups. For the two choice reaction time, the score of control (M = 0.56, SE = 0.007) group is the highest whereas the exercise (M = 0.51, SE = 0.007) and driver (M = 0.49, SE = 0.007) groups' reaction time score is similar. For the three choice reaction time score, the reaction time score of exercise (M = 0.53, SE = 0.008) group is the shortest, among control (M = 0.61, SE = 0.008) and driver (M = 0.56, SE = 0.008) groups.

4.4. Statistical analysis for the simple and choice reaction times

One of the aims of this study was to look at the difference between simple and choice reaction times to make a replication of previous studies that investigated on this purpose. One-way ANOVA was computed to compare simple visual reaction

Table 12. Means, Standard Deviations, and Standard Errors of Groups According to Dependent Variables for Left Hand

Dependent Variable	Group	*M*	*SD*	*SE*
SVRT (Min)	Control Group	.380	.045	.005
	Exercise Group	.307	.034	.005
	Driver Group	.306	.027	.005
SVRT-M (Min)	Control Group	.442	.048	.006
	Exercise Group	.382	.041	.006
	Driver Group	.368	.028	.006
TCRT (Min)	Control Group	.568	.046	.007
	Exercise Group	.513	.039	.007
	Driver Group	.493	.049	.007
ThrCRT (Min)	Control Group	.617	.057	.008
	Exercise Group	.533	.031	.008
	Driver Group	.562	.055	.008

Note: SVRT: Simple Visual Reaction Time, SVRT-M: Simple Visual Reaction Time with movement, TCRT: Two Choice Reaction Time, ThrCRT: Three Choice Reaction Time

time with movement, two and three choice reaction times.

4.4.1. Results for the right hand

Results of the ANOVA revealed (see table 13) significant difference between simple visual reaction time with movement, two choice reaction time and three choice reaction time, $F_{(2,357)}$=275.47, p <.01.

The score of simple visual reaction time with movement (*M* = 0.39, *SD* =.05) is smaller than two choice (*M* = 0.51, *SD* =.06) and three choice (*M* = 0.57, *SD* =.06) reaction times (see Table 14). The slowest reaction time is three choice's. The mean difference between simple visual reaction time with movement and two choice reaction time (p<.05) is -.123 and smaller than the mean difference between simple visual reaction time with movement and three choice reaction time (p<.05) which is -.178, whereas the mean difference between two choice reaction time and three choice reaction time (p<.05) is -.054 and smaller than all the others (Table 15, Figure 9).

Table 13. Results of the ANOVA for SVRT-M, TCRT, ThrCRT for Right Hand

	Sum of Squares	*df*	Mean Square	F	*p*
Between Groups	1.998	2	.999	275.475	.001
Within Groups	1.295	357	.004		
Total	3.292	359			

Table 14. Means and Standard Deviations of SVRT-M, TCRT, and ThrCRT for Right Hand

Dependent Variable	*M*	*SD*	*SE*
SVRT-M	.3951	.05471	.00499
TCRT	.5188	.06073	.00554
ThrCRT	.5730	.06479	.00591

Note: SVRT-M: Simple Visual Reaction Time with movement, TCRT: Two Choice Reaction Time, ThrCRT: Three Choice Reaction Time

Table 15. Mean Differences and Significance between the dependent variables SVRT-M, TCRT, and ThrCRT for Right Hand

Groups		Mean Difference	*SE*	*p*
SVRT-M	TCRT	-.123	.007	.001
	ThrCRT	-.178	.007	.001
TCRT	SVRT-M	.123	.007	.001
	ThrCRT	-.054	.007	.001
ThrCRT	SVRT-M	.178	.007	.001
	TCRT	.054	.007	.001

Note: SVRT-M: Simple Visual Reaction Time with movement, TCRT: Two Choice Reaction Time, ThrCRT: Three Choice Reaction Time

4.4.2. Results for the left hand

Results of the ANOVA revealed (see table 16) significant difference between simple visual reaction time with movement, two choice reaction time and three choice reaction time, $F_{(2,357)}$=309.60, p <.01.

Table 16. Results of the ANOVA for SVRT-M, TCRT, ThrCRT for Left Hand

	Sum of Squares	*df*	Mean Square	F	*p*
Between Groups	1.932	2	.966	309.598	.001
Within Groups	1.114	357	.003		
Total	3.046	359			

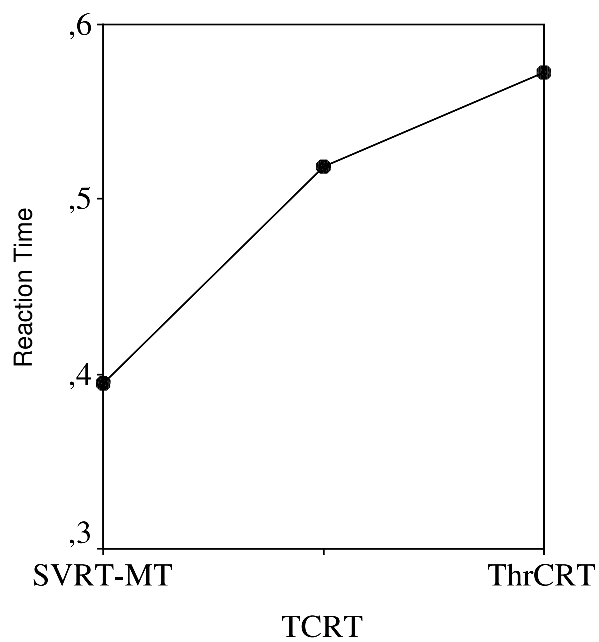

Figure 9. Plot of Means for SVRT-M, TCRT, and ThrCRT for Right Hand

The score of simple visual reaction time with movement (*M* = 0.39, *SD* =.05) is smaller than two choice (*M* = 0.52, *SD* =.05) and three choice (*M* = 0.57, *SD* =.06) reaction times (see Table 17). The slowest reaction time is three choice's. The mean difference between simple visual reaction time with movement and two choice reaction time (p<.05) is -.127 and smaller than the mean difference between simple visual reaction time with movement and three choice reaction time (*p*<.05) which is -.173, whereas the mean difference between two choice reaction time and three choice reaction time (*p*<.05) is -.046 and smaller than all the others (Table 18, Figure 10).

Table 17. Means and Standard Deviations of SVRT-M, TCRT, and ThrCRT for Left Hand

Dependent Variable	N	*M*	*SD*	*SE*
SVRT-M	120	.3974	.05149	.00470
TCRT	120	.5245	.05521	.00504
ThrCRT	120	.5707	.06050	.00552

Note: SVRT-M: Simple Visual Reaction Time with movement, TCRT: Two Choice Reaction Time, ThrCRT: Three Choice Reaction Time

Table 18. Mean Differences and Significance between the dependent variables SVRT-M, TCRT, and ThrCRT for Left Hand

Groups		Mean Difference	*SE*	*p*
SVRT-M	TCRT	-.127	.007	.001
	ThrCRT	-.173	.007	.001
TCRT	SVRT-M	.127	.007	.001
	ThrCRT	-.046	.007	.001
ThrCRT	SVRT-M	.173	.007	.001
	TCRT	.046	.007	.001

Note: SVRT-M: Simple Visual Reaction Time with movement, TCRT: Two Choice Reaction Time, ThrCRT: Three Choice Reaction Time

4.5. Statistical analysis for the hand dominance

Reaction time scores of dominant hand and non-dominant hand was compared to see if there is any difference between them. Therefore, besides the interaction, the main effect of them also reported. According to the result of factorial MANOVA significant main effect was not found on hand dominance, Wilks' Lambda=.99, $F_{(5,114)}$= .189, *p* >.05, and $\eta = .01$ which is a small effect (Table 19).

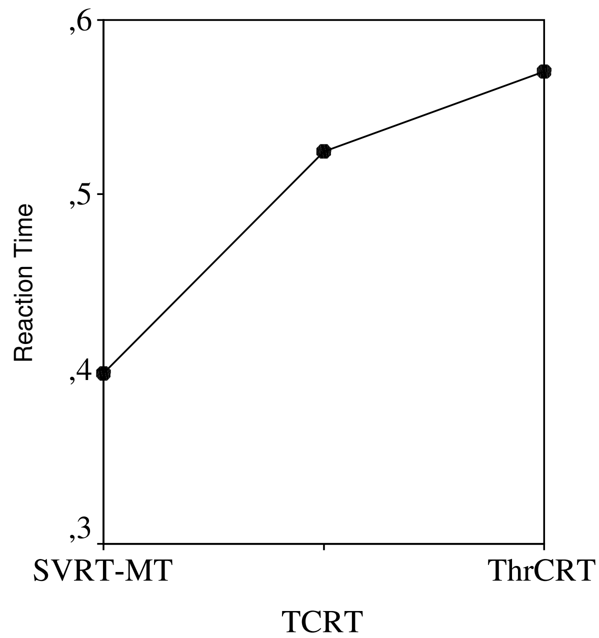

Figure 10. Plot of Means for SVRT-M, TCRT, and ThrCRT for Left Hand

Table 19. Main Effects and Significance of Hand Dominance

Effect	Value	*F*	Hypothesis *df*	Error *df*	*p*	η
Intercept	.009	2411.589	5	114	.001	.991
Dominance	.992	.189	5	114	.966	.008

Results of the MANOVA revealed (see table 20) that there was no significant main effect for simple auditory reaction time (SART) $F_{(1,118)}$= 0.001, p >.01, and $\eta = .001$ which is a small effect, simple visual reaction time (SVRT) $F_{(1,118)}$= 0.166, p >.01, and $\eta = .001$ which is a small effect, simple visual reaction time with movement (SVRT-M) $F_{(1,118)}$= 0.053, p >.01, and $\eta = .001$ which is a small effect, two choice reaction time (TCRT) $F_{(1,118)}$= 0.343, p >.01, and $\eta = .003$ which is a small effect, and three choice reaction time (ThrCRT) $F_{(1,118)}$= 0.002, p >.01, and $\eta = .001$ which is a small effect.

Table 20. Main Effects and Significance of Dependent Variables on Hand Dominance

Source	Dependent Variable	*df*	Mean Square	*F*	*p*	η
Dominance	SVRT	1	.001	.166	.684	.001
	SVRT-M	1	.001	.053	.818	.001
	TCRT	1	.001	.343	.559	.003
	ThrCRT	1	7.008	.002	.967	.001
Error	SVRT	118	.003			
	SVRT-M	118	.003			
	TCRT	118	.003			
	ThrCRT	118	.004			

Note: SVRT: Simple Visual Reaction Time, SVRT-M: Simple Visual Reaction Time with movement, TCRT: Two Choice Reaction Time, ThrCRT: Three Choice Reaction Time

The score of dominant hand was similar with that of non-dominant hand for simple visual reaction time with movement (for dominant hand *M* = 0.39, *SD* =.05, for non-dominant hand *M* = 0.39, *SD* =.05), and for three choice reaction time (for dominant hand *M* = 0.57, *SD* =.06, for non-dominant hand *M* = 0.57, *SD* =.05). The score of dominant hand is smaller than that of non-dominant hand for simple visual reaction time (for dominant hand *M* = 0.32, *SD* =.05, for non-dominant hand *M* = 0.33, *SD* =.04), and for two choice reaction time (for dominant hand *M* = 0.51, *SD* =.05, for non-dominant hand *M* = 0.52, *SD* =.05) (Table 21).

Table 21. Means, Standard Deviations, and Standard Errors of Dependent Variables on Hand Dominance

Dependent Variable	Dominance	*M*	*SD*	*SE*
SVRT	Dominant Hand	.327	.055	.007
	Non-Dominant Hand	.331	.048	.007
SVRT-M	Dominant Hand	.395	.056	.007
	Non-Dominant Hand	.397	.051	.007
TCRT	Dominant Hand	.518	.056	.007
	Non-Dominant Hand	.524	.056	.007
ThrCRT	Dominant Hand	.570	.068	.008
	Non-Dominant Hand	.570	.057	.008

Note: SVRT: Simple Visual Reaction Time, SVRT-M: Simple Visual Reaction Time with movement, TCRT: Two Choice Reaction Time, ThrCRT: Three Choice Reaction Time

CHAPTER 5

DISCUSSION

The purpose of this study was to investigate the variable effects of sport participation and driving on sex differences in visual reaction time. Convenient with the purpose, this research had some questions on the reaction time and sex differences between the all groups, and the degree of those differences between each groups. In the following section, each hypothesis in the result of the study will be stated and discussed in line with the current literature.

There were three primary hypotheses and two secondary hypotheses. First, it was hypothesized that there was no sex and group interaction between males and females of control, exercise, and driver groups. The results failed to support the first primary hypothesis. There was a statistically significant sex and group interaction for both hands consistently. This finding is contradictory to the literature that there is no interaction between sexes in reaction times (Linford et al., 2006). Linford et al. (2006) examined the influence of a 6-week neuromuscular training program on the electromechanical delay and reaction time of the peroneus longus muscle. In the study of Linford et al. (2006), twenty-six healthy, physically active, college-age subjects took part. There were 5 men and 8 women (mean age = 21.9) in the treatment group and 6 men and 7 women (mean age = 21.8) in the control group. According to their results, neuromuscular training caused a decrease in reaction time. They had not found significant difference between sexes or the interaction of sex and treatment in either reaction time or electromechanical delay. In the present study, in simple visual reaction time, sex differences in driver and exercise groups were similar and smaller than control group. While females were the slowest performers in the control group for simple visual reaction time, they are faster than males if they do long-term exercise at competitive level, and driving extensively. For simple visual reaction time with movement, however males were faster than females in control and exercise groups, they are slower in driver group. Since reaction time and movement time are two separate categories, which is that movement time begins when reaction time ends (Coker, 2004; Magill, 2004), the result showed in the sense that males had not better movement times than females because of the fact that males were worse than females in simple visual reaction time. Sex differences were least in the driver group and greatest in the control group for simple visual reaction time with movement. There was nearly no sex difference in driver group. However, sex difference in exercise group is much more in simple visual reaction time with movement than simple visual reaction time, and they are similar with two choice reaction time. Males in exercise and driver groups had very similar scores in simple visual reaction time with movement. For the two choice reaction time, males in control and exercise groups had alike scores, whereas the score difference between them is less than the score difference between females control and exercise groups. The exercise and driver groups' females had similar two choice reaction time scores. The fastest two choice reaction time score belongs to males in driver group but there was little difference between driver female and driver male groups. In all the categories of reaction time, score difference between females in control group and females in exercise and driver groups was much more than the score difference between males in control group and males in exercise and driver groups. Exercise and driving improves reaction times of females most. In the light of all these results, it is obvious that driving decreases reaction times. The sex difference is least in simple visual reaction time. Female scores approximate male scores mostly in simple visual reaction time. That means that exercise and driving help decreasing mostly the simple visual reaction time. Also, there were not much obvious effect of exercise and driving on the reaction time scores of males as in those of females. Besides, fundamentally, sex difference on reaction time decreases furthest with the effect of driving. As mentioned earlier, Silverman (2006) stated that women have a natural advantage over men in reaction time because women are on average smaller than men. Therefore, the neural impulses involved in the production of a motor response have less far to travel in women than in men. Moreover, Silverman (2006) reported evidence that the male advantage in visual reaction time is getting smaller (especially outside the US), possibly because more women are participating in driving and fast-action sports.

Second, there was no statistically significant difference between the reaction time scores of males and females. Second hypothesis was also not supported. There was statistically significant difference between the reaction time scores of males and females for both hands. The fastest reaction times for all the categories of it belonged to males. The smallest difference between the scores of males and females were in simple visual reaction time and two choice reaction time. This result was in line with some literature that males have faster reaction times than females (Liu et al., 2006; Adam et al., 1999; Silverman, 2006). But it is contradictory to some literature too. Linford et al. (2006) found no difference between sexes in reaction times. This contradictory results might be caused from the insufficient number of the participants in the study.

Third, there was no statistically significant difference between the reaction time scores of control, exercise, and driver groups. Third, it was hypothesized that there was no statistically significant difference between the reaction time scores of control, exercise, and driver groups. But it was failed to support too, that, there were statistically significant difference between groups. Results were consistent for right and left hands. Driver group had fastest reaction times in three categories, which are that simple visual reaction time, simple visual reaction time with movement, and two choice reaction time. Beside, exercise group had fastest reaction times in one category, which is that three choice reaction time. The fact that those two groups have shorter results in different reaction time categories, there should have been some reasons for such results. It could be normal for driver to have shorter simple visual reaction times and simple visual reaction times with movement because the visuality in the traffic is a vital importance (D'Orazio, Leo, Guaragnella, & Distante, 2007; Underwood, 2007). Also, since they are in a situation, which is open to probabilities as either move or stop, their two choice reaction time improved. But the exercise group has better score on three choice reaction time. It could be because of the fact that every probability is possible in taekwondo, the exercise group might be improved in decision making, which covers reaction times that require more than two choice. The result that exercise decreases reaction time is consistent with the literature (Yagi et al., 1999; Ando et al., 2002; Davranche et al., 2006). At the same time, it is contrary to some literature, which reached the result that exercise have no effect on reaction times (Taniguchi, 1999; Mcmorris et al., 2000; Endo et al., 2006). But there was a weakness in the study of Taniguchi (1999) that the insufficient number of participants, which were 4 female and 23 male to be divided into 4 groups, as stated before. Similarly, Endo et al. (2006) explained the unexpected result of their study, which was that there was no significant difference between the reaction times of athletes and those of non-athletes, as the result of insufficient number of subjects to reliably discuss the reaction time difference. There were 20 right handed athlete (10 males) and non-athlete (10 males), and the age range was 23-33 years old. They tested primary motor cortex activity during a reaction time task to examine the appearance of motor cortex activity that synchronized with the stimulus presentation. Mcmorris et al. (2000) declared their weakness of the study as to replicate using more complex skill tests.

At the beginning of the study, it was expected some secondary hypotheses. First secondary hypothesis was that simple reaction times were not statistically better than the choice reaction times for all groups and sexes. It was rejected according to the results. The general tendency of the literature showed that simple reaction time is shorter than the choice reaction time (Rosenbaum, 1991; Oxendine, 1968). The result of the current study supported this idea that the simple reaction time was much more shorter than the choice reaction time. The relationship between stimulus and response alternatives was same for right and left hands. Also, two choice reaction time was significantly shorter than three choice reaction time. In addition, the difference between two and three choice reaction time scores is smaller than the difference between simple and choice reaction times. Such additive result reminded that there were other factors that affect making choice. For instance, as mentioned earlier, stimulus-response compatibility is an important factor nearly in all kinds of reaction time tasks (Rosenbaum, 1991). If the stimulus-response alternatives increase, choice reaction time also increases (Hick, 1952; Hyman, 1953). This is a relation known as the Hick-Hyman Law (Schmidt, et al., 2000; Coker, 2004; Rosenbaum, 1991).

It can be postulated that since the majority of the participants were right-handed, hand dominance would be a factor that affected such inconsistent result. However, there was no statistically significant difference between dominant and non-dominant hands on reaction times. The reaction time scores of dominant and non-dominant hands were very similar for all the categories. The result of hand dominance was contradictory to the literature. The previous studies indicated that left hand would be faster than right hand (Boulinquez et al., 2000; Bartélémy et al., 2001, & 2002), and dominant hands would be generally faster than non-dominant hands (Peters et al., 1999). Boulinquez et al. (2000), and Bartélémy et al. (2001, & 2002) suggested that the hemispheres of the cerebrum are specialized for different tasks. The left hemisphere is regarded as the verbal and logical brain, and the right hemisphere is thought to govern creativity and spatial relations, among other things. Also, the right hemisphere controls the left hand, and the left hemisphere controls the right hand. They thought that the situation has made researchers think that the left hand should be faster at reaction times involving spatial relationships such as pointing at a target.

In conclusion, this study was designed to investigate two factors that could decrease the sex differences in reaction times. Sex is only one factor that could affect reaction time. Two factors, which are that exercise and driving, that could have effects on sex difference on reaction times handled to focus on their effects. This study indicated that both long-term exercise and driving extensively resulted in the reduction of visual reaction times between males and females. Both driving extensively and prolonged exercise seem to have a similar effect. Therefore, it can be inferred that, sex difference in visual reaction times is decreasing with the effect of long-term exercise and extensive driving. There are some suppositions for the reason of decreasing sex difference in reaction times with the effect of exercise and driving. From the very beginning of the history, men have had the duty of hunting or works that require muscle force because of their muscle structure whereas women have had the duty of caring for children or house works. The situation of work sharing put the women in a passive position while the men in an active position. The reaction times of women were slower than men probably because of the fact that women were exposed to close environment and not to an environment required active position. If the women received the same effects as men were exposed to, their reaction times would decrease. Since, this study found that the exercise and driving affect reaction time positively, they would be incorporated in life more to get faster reaction times. The reaction times of women in driver group were better than in other groups.

Therefore, the general assumption in the community that, women drivers are slower than men was only a perception. Because, women do not react indifferently according to the results of this study. That perception can be abated via education since it is a socio-cultural perception. Also, the results showed that driving is a trainable activity as far as it is also dangerous. Therefore, an education may be given to make drivers more accurate people. Based on the result of this study, future research is warranted to determine the effects of different types of sports on reaction time. In this study, only one sport branch, which was taekwondo, was included. Comparison between different sports that reaction time has importance on and the sports that reaction time has no importance on can be studied. Another line of future direction is pre-post comparison of sex differences due to exercise and no exercise.

REFERENCES

Abernaty, B. (1991). Visual search strategies and decision-making in sport. *International Journal of Sport Psychology, 68*, 189-210.

Adam, J. J., Janssen, G. M. E., Paas, F. G. W. C., & Vrencken, J. G. P. M. (1994). Effects of a 10-Month endurance program on performance of speeded perceptual-motor tasks. *Perceptual and Motor Skills, 16*, 1267-1273.

Adam, J. J., Paas F. G. W. C., Buekers M. J., Wuyts I. J., Spijkers W. A. C., & Wallmeyer P. (1999). Gender differences in choice reaction time: Evidence for differential strategies. *Ergonomics, 42*, 327-335.

Ainslie, P. N., Campbell, I, T., Frayn, K. N., Humphreys, S. M., MacLaren, D. P. M., & Reilly, T. (2003). Physiological, metabolic, and performance implications of a prolonged hill walk: Influence of energy intake. *Journal of Applied Physiology, 94*, 1075-1083.

Alford, C., Cox, H., & Wescott, R. (2001). The effects of Red Bull Energy Drink on human performance and mood. *Amino Acids, 21*, 139-150.

Ando, S., Kida, N., & Oda, S. (2002). Practice effects on reaction time for peripheral and central visual fields. *Perceptual and Motor Skills, 95*, 747-751.

Ando, S, Kida, N., & Oda, S. (2004). Retention of practice effects on simple reaction time for peripheral and central visual fields. *Perceptual and Motor Skills, 98*, 897-900.

Ando, S., Kimura, T., Hamada, T., Kokubu, M., Moritani, T., & Oda, S. (2005). Increase in reaction time for peripheral visual field during exercise above the ventilatory threshold. *European Journal of Applied Physiology, 94*, 461-467.

Anstey, K. J., Wood, J., Lord, S., & Walker, J. G. (2005). Cognitive, sensory and physical factors enabling driving safety in older adults. *Clinical Psychology Review, 25*, 45-65.

Arcelin, R., Delignieres, D., & Brisswalter, J. (1998). Selective effects of physcial exercise on choice reaction processes. *Perceptual and Motor Skills, 87*, 175-185.

Ari, Z., Kutlu, N., Uyanık, B. S., Taneli, F., Büyükyazı, G., & Tavlı, T. (2004). Serum testosterone, growth hormone, and insulin-like growth factor-1 levels, mental reaction time, and maximal aerobic exercise in sedentary and long-term physically trained elderly males. *International Journal of Neuroscience, 114*, 623-637.

Audiffren, M., Brisswalter, J., Brandet, J. P., & Bosquet, L. (1998). The relation of exercise intensity to attention deficit: Analysis of a cycling task. *Science & Sports, 13*, 81-83.

Barnett, A., Smith, B., Lord, S. R., Williams, M., & Baumand, A. (2003). Community-based group exercise improves balance and reduces falls in at-risk older people: A randomised controlled trial. *Age and Ageing, 32*, 407-414.

Barral, J., & Debu, B. (2004). Aiming in adults: Sex and laterality effects. *Laterality: Assymmetries of Body, Brain and Cognition, 9*, 299-312.

Barthélémy, S., & Boulinguez P. (2001). Manual reaction time asymmetries in human subjects: The role of movement planning and attention. *Neuroscience Letters*, *315,* 41-44.

Barthélémy, S., & Boulinguez, P. (2002). Orienting visuospatial attention generates manual reaction time asymmetries in target detection and pointing. *Behavioral Brain Research, 133*, 109-116.

Basgoze, O., Hascelik, Z., Narman, S., Ozker, R., & Turker, K. (1989). The effects of physical training on physical fitness tests and auditory and visual reaction times of volleyball players. *The Journal of Sports Medicine and Physical Fitness, 29*, 234-238.

Bender, S., Resch, F., Weisbrod, M., & Oelkers-Ax, R. (2004). Specific task anticipation versus unspecific orienting reaction during early contingent negative variation. *Clinical Neurophysiology, 115*, 1836-1845.

Bertelson, P. (1967). The time course of preparation. *Quarterly Journal of Experimental Psychology, 19*, 272-279.

Boulinguez. P., & Barthélémy, S. (2000). Influence of the movement parameter to be controlled on manual RT asymmetries in right-handers. *Brain and Cognition, 44*, 653-661.

Brebner, J. T. (1980*). Reaction time in personality theory. Reaction Times.* New York: Academic Pres.

Brebner, J. T., & Welford, A. T. (1980). *Introduction: An historical background sketch.* New York: Academic Press.

Brisswalter, J., Arcelin, R., Audiffren, M., & Delignieres, D. (1997). Influence of physical exercise on simple reaction time : Effect of physical fitness. *Perceptual and Motor Skills, 85*, 1019-1027.

Bryden, P. (2002). Pushing the limits of task difficulty for the right and left hands in manual aiming. *Brain and Cognition, 48*, 287-291.

Buchman, A. S., Wilson, R. S., Bienias, J. L., & Bennett, D. A. (2005). Gender differences in upper extremity motor performance of older persons. *Geriatrics and Gerontology International, 5*, 59-65.

Butchiramaiah, C., Khan, H. A., & Sharma, V. (1986). A comparative study of reaction time and concentration among recreational and competitive volleyball players. *SNIPES – Journal, 10*, 40-46.

Castell, S., & Lord, S. R. (1994). Physical activity program for older persons: Effect on balance, strength, neuromuscular control, and reaction time. *Archives of Physiology, Medicine and Rehabilitation, 75*, 648-652.

Chmura, J., Nazar, K., & Kaciubauscilko, H. (1994). Choice-reaction time during graded-exercise in relation to blood lactate and plasma-catecholamine thresholds. *International Journal of Sports Medicine, 15*, 172-176.

Cnossen, F., Meijman, T., & Rothengatter, T. (2004). Adaptive strategy changes as a function of task demands: A study of car drivers. *Ergonomics, 47*, 218-236.

Coker, C. A. (2004). *Motor learning and control for practitioners*. New York: McGraw-Hill.

Collardeau, M., Brisswalter, J., & Audiffren, M. (2001a). Effects of prolonged run on simple reaction time of well trained runners. *Perceptual and Motor Skills, 93*, 679-689.

Collardeau, M., Brisswalter, J., Vercruyssen, F., Audiffren, M., & Goubault, C. (2001b). Single and choice reaction time during prolonged exercise in trained subjects : Influence of carbohydrate availability. *European Journal of Applied Physiology, 86*, 150-156.

Collins, M. W., Field, M., Lovell, M. R., Iverson, G., Johnston, K. M., Maroon, J., & Fu, F. H. (2003). Relationship between post concussion headache and neuropsychological test performance in high school athletes. *The American Journal of Sports Medicine,31*, 168-174.

Dane, S., & Erzurumluoglu, A. (2003). Sex and handedness differences in eye-hand visual reaction times in handball players. *International Journal of Neuroscience, 113*, 923-929.

Davranche, K., & Audiffren, M. (2004). Facilitating effects of exercise on information processing. *Journal of Sport Sciences, 22*, 419-428.

Davranche, K., Burle, B., Audiffren, M., & Hasbroucq, T. (2005). Information processing during physical exercise : A chronometric and electromyographic study. *Experimental Brain Research, 165*, 532-540.

Davranche, K., Burle, B., Audiffren, M., & Hasbroucq, T. (2006). Physical exercise facilitates motor processes in simple reaction time performance: An electromyographic analysis. *Neuroscience Letters, 396*, 54-56.

Deary, I. J., Der, G., & Ford, G. (2001). Reaction times and intelligence differences: A population-based cohort study. *Intelligence, 29*, 389.

Der, G., & Deary, I. J. (2003). IQ, reaction time and the differentiation hypothesis. *Intelligence, 31*, 491–503.

Der, G., & Deary, I. J. (2006). Age and sex differences in reaction time in adulthood: Results from the United Kingdom Health and Lifestyle survey. *Psychology & Aging, 21*, 62-73.

Dickstein, R., Hocherman, S., Amdor, G., & Pillar, T. (1993). Reaction and movement times in patients with hemiparesis for unilateral and bilateral elbow flexion. *Physical Therapy, 73*, 374-385.

Donders, F. C. (1868). On the speed of mental processes. Translated by Koster, W. G. (1969). *Acta Psychologica*,*30*, 412-431.

D'Orazio, T., Leo, M., Guaragnella, C., & Distante, A. (2007). A visual approach for driver inattention detection. *Pattern Recognition, 40*, 2341-2355.

Duinen, H. V., Lorist, M. M., & Zijdewind, I. (2005). The effect of caffeine on cognitive task performance and motor fatigue. *Psychopharmacology, 180*, 539-547.

Durst, L., Harbin, D., & Harbin, G. (1989). Evaluation of oculomotor response in relation to sports performance. *Medicine and Science in Sports and Medicine, 21*, 258-262.

Edinger, J. D., Glenn, D. M., Bastian, L. A., & Marsh, G. R. (2000). Slow-wave sleep and waking cognitive performance II: Findings among middle-aged adults with and without insomnia complaints. *Physiology & Behavior, 70*, 127-134.

Edwards, D. J., &Rikli, R. E. (1991). Effects of a three year exercise program on motor function and cognitive processing speed in older women. *Research Quarterly for Exercise and Sport, 24*, 61-67.

Endo, H., Kato, Y., Kizuka, T., & Takeda, T. (2006). A comparison of stimulus synchoronous activity in the primary motor cortices of athletes and non-athletes. *Experimental Brain Research, 174*, 426-434.

Engel, B. T., Thorne, P. R., & Quilter, R. E. (1972). On the relationship among sex, age, response mode, cardiac cycle phase, breathing cycle phase, and simple reaction time. *Journal of Gerontology, 27*, 456-460.

Escher, S. A., Tucker, A. M., Lundin, T. M., & Grabiner, M. D. (1998). Smokeless tobacco, reaction time, and strength in athletes. *Medicine and Science in Sports and Exercise, 30*, 1548-1551.

Etnyre, B., & Kinugasa, T. (2002). Postcontraction influences on reaction time (motor control and learning). *Research Quaterly for Exerciseand Sport, 73*, 271-282.

Falkenstein, M., Willemssen, R., Hohnsbein, J., & Hielscher, H. (2006). Effects of stimulus-response compatibility in Parkinson's disease: A psychophysiological analysis. *Journal of Neural Transmission, 113*, 1449-1462.

Fillmore, M. T., & Blackburn, J. (2002). Compensating for alcohol-induced impairment: alcohol expectancies and behavioral disinhibition. *Journal of Studies on Alcohol, 63*, 237.

Fletcher, S. G., Smith, S. C., & Hasegawa, A. (1985). Vocal/Verbal response times of normal-hearing and hearing-impaired children. *Journal of Speech and Hearing Research, 28*, 548-555.

Fontani, G., Lodi, L., Felici, A., Migliorini S., & Corradeschi, F. (2006). Attention in athletes of high and low experience enganged in different open skill sports. *Perceptual and Motor Skills, 102*, 791-816.

Gutierrez, A., Gonzalez-Gross, M., Delgado, M., & Castillo, M. J. (2001). Three days fast in sportsmen decrease physical work capacity but not strength or perception-reaction time. *International Journal of Sport Nutrition and Exercise Metabolism, 11*, 420.

Günendi Z., Taşkıran, O. O., & Beyazova, M. (2005). What is the optimal repetition number in electromyographic reaction time studies?. *Clinical Biomechanics, 20*, 754-758.

Hardy, D. J., & Hinkin, C. H. (2002). Reaction time performance in adults with HIV/AIDS. *Journal of Clinical and Experimental Neuropsychology, 24*, 912-929.

Hernandez, O. H., Vogel-Sprott, M., Huchin-Ramirez, T., & Aké-Estrada, F. (2005). Acute dose of alcohol affects cognitive components of reaction time to an omitted stimulus: Differences among sensory systems. *Psychopharmacology, 184*, 75-81.

Hick, W. E. (1952). On the rate of gain of information. *Quarterly Journal of Experimental Psychology, 4*, 11-26.

Hopkins, W. D., Morris, R. D., Savage-Rumbaugh, E. S., & Rumbaugh, D. M. (1992). Hemispheric priming by meaningful and nonmeaningful symbols in language trained chimpanzees (Pan troglodytes): Further evidence of a left hemisphere advantage. *Behavioral Neuroscience, 106*, 575-582.

Hsieh, S. (2002). Tasking shifting in dual-task settings. *Perceptual and Motor Skills, 94*, 407.

Hyman, R. (1953). Stimulus information as a determinant of reaction time. *Journal of Experimental Psychology, 45*, 188-196.

Ishijima, T., Hirai, T., Koshino, H., Konishi, Y., & Yokoyama, Y. (1998). The relationship between occlusal support and physical exercise ability. *Journal of Oral Rehabilitation, 25*, 468-471.

Iudice, A., Bonanni, E., Gelli, A., Frittelli, C., Iudice, G., Cignoni, F., Ghicopulos, I., & Murri, L. (2005). Effetcs of prolonged wakefulness combined with alcohol and hands-free cell phone divided attention tasks on simulated driving. *Human Psychopharmacology: Clinical and Experimental 20*, 125-132

Jacobson, B., & Thurmanlacey, S. (1992). The effect of caffeine on motor-performance by caffeine-naive and caffeine-familiar subjects. *Perceptual and Motor Skills, 74*, 151-157.

Jenkins, S., & McLeod, P. (1991). Timing accuracy and decision time in high speed ball games. *International Journal of Sport Psychology, 22*, 279-295.

Jevas, S., & Yan, J. H. (2001). The effect of aging on cognitive function: A preliminary quantitative review. *Research Quarterly for Exercise and Sport, 72*, A-49.

Junge, A., Dvorak, J., Rosch, D., Graf-Baumann, T., Chomiak, J., & Peterson, L. (2000). Psychological and sport-specific characteristics of football players. *American Journal of Sports Medicine, 28*, S22-S28.

Kamijo, K., Nishihira, Y., Hatta, A., Kaneda, T., Kida, T., Higashiura, T., & Kuroiwa, K. (2004). Changes in arousal level by differential exercise intensity. *Clinical Neurophysiology, 115*, 2693-2698.

Kashihara, K., & Nakahara, Y. (2005). Short-term effect of physical exercise at lactate threshold on choice reaction time. *Perceptual and Motor Skills, 100*, 275-281.

Kemp, B. J. (1973). Reaction time of young and elderly subjects in relation to perceptual deprivation and signal-on versus signal-off condition. *Developmental Psychology, 8*, 268-272.

Kokubu, M., Ando, S., Kida, N., & Oda, S. (2006). Interference effects between saccadic and key-press reaction times of volleyball players and nonathletes. *Perceptual & Motor Skills, 103*, 709-716.

Kruisselbrink, L. D., Martin, K. L., Megeney, M., Fowles, J. R., & Murphy, R. J. L. (2006). Physical and psychomotor functioning of females the morning after consuming low to moderate quantities of beer. *Journal of Studies on Alcohol, 67*, 416-421.

Kruk, B., Chmura, J., Krzeminski, K., Ziemba, A. W., Nazar, K., Pekkarinen, H., & Kaciuba-Uscilko, H. (2001). Influence of caffeine, cold and exercise on multiple choice reaction time. *Psychopharmacology, 157*, 197-201.

Kubesch, S., Bretschneider, V., Freudenmann, R., Weidenhammer, N., Lehmann, M., Spitzer, M., & Gron, G. (2003). Aerobic endurance exercise improves executive functions in depressed patients. *Journal of Clinical Psychiatry, 64*, 1005-1012.

Kujala, U. M., & Taimela, S. (1992). Reaction times with reference to musculoskeletal complaints in adolescence. *Perceptual and Motor Skills, 78*, 1075-1082.

Lajoie, Y., & Gallagher, S. P. (2004). Predicting falls within the elderly community: Comparison of postural sway, reaction time, the Berg balance scale and the Activities-specific Balance Confidence (ABC) scale for comparing fallers and non-fallers. *Archives of Gerontology and Geriatrics, 38*, 11-25.

Lamble, D., Summala, H., & Hyvarinen, L. (2002). Driving performance of drivers with impaired central visual field acuity. *Accident Analysis and Prevention, 34*, 711-716.

Lemmink, K., & Visscher, C. (2005). Effect of intermittent exercise on multiple-choice reaction times of soccer players. *Perceptual and Motor Skills, 100*, 85-95.

Lenzenweger, M. F. (2001). Reaction time slowing during high-load, sustained-attention task performance in relation to psychometrically identified schizotypy. *Journal of Abnormal Psychology,110*, 290.

Liguori, A., & Robinson, J. H. (2001). Caffeine anatagonism of alcohol-induced driving impairment. *Drug and Alcohol Dependence, 63*, 123-129.

Lin, C. J., & Chen, H. J. (2006). Verbal and cognitive distractors in driving performance while using hands-free phones. *Perceptual and Motor Skills, 103*, 803-810.

Linford, C. W., Hopkins, J. T., Schulties, S. S., Freland, B., Draper, D. O., & Hunter, L. (2006). Effects of neuromuscular training on the reaction time and electromechanical delay of the peroneus longus muscle. *Archives of Physical Medicine and Rehabilitation, 87,* 395-401.

Liu, N., Zhou, D., Li, B., Ma, Y., & Hu, X. (2006). Gender related effects of heroin abuse on the simple reaction time task. *Addictive Behaviors, 31*, 187-190.

Lord, S. R., Castell, S., Corcoran, J., Dayhew, J., Matters, B., Shan, A., & Williams, P. (2003). The effect of group exercise on physcial functioning and falls in frail older people living in retirement villages: A randomized, controlled trial. *Journal of the American Geriatrics Society, 51*, 1685-1692.

Lord, S. R., Ward, J. A.i & Williams, P. (1996). Exercise effect on dynamic stability in older women; a randomized controlled trial. *Archives of Physiology, Medicine, and Rehabilitation, 77*, 232-236.

Luce, R. D. (1986). *Response times: Their role in inferring elementary mental organization.* New York: Oxford University Press.

Luchies, C. W., Schiffman, J., Richards, L. G., Thompson, M. R., Bazuin, D., & DeYoung, A. J. (2002). Effects of age, step direction, and reaction condition on the ability to step quickly. *The Journals of Gerontology, A57*, M246.

Lupinacci, N. S., Rikli, R. E., Jones, C. J., & Ross, D. (1993). Age and physical-activity effects on reaction-time and digit symbol substitution performance in cognitively active adults. *Research Quarterly for Exercise and Sport, 64*, 144-150.

Magill, R. A. (2004). *Motor learning and control concepts and applications* (7th ed.). New York: McGraw-Hill.

Marigold, D. S., Eng, J. J., Dawson, A. S., Inglis, J. T., Harris, J. E., & Gylfadottir (2005). Exercise leads to faster postural reflexes, improved balance and mobility, and fewer falls in older persons with chronic stroke. *Journal of the American Geriatrics Society, 53*, 416-423.

Marshall, W. H., Talbot, S. A., & Ades, H. W. (1943). Cortical response of the anaesthesized cat to gross photic and electrical afferent stimulation. *Journal of Nerophysiology, 6*, 1-15.

Masanobu, A., & Choshi, K. (2006). Contingent muscular tension during a choice reaction task. *Perceptual and Motor Skills, 102*, 736-747.

McKnight, A. J., & McKnight, A. S. (1999). Multivariate analysis of age-related driver ability and performance deficits. *Accident Analysis and Prevention, 31*, 445-454.

McMorris, T., Harris, R. C., Swain, J., Corbett, J., Collard, K., Dyson, R. J., Dye, L., Hodgson, C., & Draper, N. (2006). Effect of creatine supplementation and sleep deprivation, with mild exercise, on cognitive and psychomotor performance, mood state, and plasma concentrations of catecholamines and cortisol. *Psychopharmacology, 185*, 93-103.

McMorris, T., & Keen, P. (1994). Effect of exercise on simple reaction-times of recreational athletes. *Perceptual and Motor Skills, 78*, 123-130.

McMorris, T., Sproule, J., Draper, S., & Child, R. (2000). Performance of a psychomotor skill following rest, exercise at the plasma epinephrine threshold and maximal intensity exercise. *Perceptual and Motor Skills, 91*, 553-562.

McMorris, T., Tallon, M., Williams, C., Sproule, J., Draper, S., Swain , J., Potter, J., & Clayton, N. (2003). Incremental exercise, plasma concentrations of catecholamines, reaction time, and motor time during performance of a noncompatible choice response time task. *Perceptual and Motor Skills, 97*, 590-604.

Miller, J. O., & Low, K. (2001). Motor processes in simple, go/no-go, and choice reaction time tasks: A psychphysiological analysis. *Journal of Experimental Psychology: Human Perception and Performance*, *27*, 266.

Montano, L., & Whitley, J. D. (1992). Relation between reaction time and movement time in college wrestlers. *Perceptual and Motor Skills, 74*, 171-176.

Mori, S., Ohtani, Y., & Imanaka, K. (2002). Reaction times and anticipatory skills of karate athletes. *Human Movement Science, 21*, 213-230.

Nettelbeck, T. (1980). *Factors affecting reaction time: Mental retardation, brain damage, and other psychopathologies.* New York: Academic Press.

Neubauer, A. C., & Knorr, E. (1997). Elementary cognitive processes in choice reaction time tasks and their correlations with intelligence. *Personality and Individual Differences, 23*, 715-728.

Odenheimer, G. L., Beaudet, M., Jette, A. M., Albert, M. S., Grande, L., & Minaker, K. L. (1994). Performance-based driving evaluation of the elderly driver: Safety, reliability, and validity. *Journals of Gerontology, 49*, 153-159.

Oxendine, J. B. (1968). *Psychology of motor learning*. New Jersey: Prentice-Hall.

Paasuke, M., Ereline, J., & Gapeyeva, H. (1999). Neuromuscular fatigue during repeated exhaustive submaximal static contractions of knee extensor muscles in endurance-trained, power-trained and untrained men. *Acta Physiologica Scandinavica, 166*, 319-326.

Pallant, J. (2001). *SPSS survival manual*. Philadelphia: Open University Press.

Perruchet, P., Cleeremans, A., & Destrebecqz, A. (2006). Dissociating the effects of automatic activation and explicit expectancy on reaction times in a simple associative learning task. *Journal of Experimental Psychology: Learning, Memory and Cognition, 32*, 955-966.

Peters, M., & Ivanoff, J. (1999). Performance asymmetries in computer mouse control of right-handers, and left-handers with left- and right-handed mouse experience. *Journal of Motor Behavior, 31*, 86-94.

Philip, P., Sagaspe, P., Moore, N., Taillard, J., Charles, A., Guilleminault, C., & Bioulac, B. (2005). Fatigue, sleep restriction and driving performance. *Accident Analysis and Prevention, 37*, 473-478.

Philip, P., Taillard, J., Sagaspe, P., Valtat, C., Sanchez-Ortuno, M., Moore, N., Charles, A., & Bioulac, B. (2004). Age, performance, and sleep deprivation. *Journal of Sleep Research, 13*, 105-110.

Rae C., Digney A. L., McEwan S. R., & Bates T. C. (2003). Oral creatine monohydrate supplementation improves brain performance: A double-blind, placebo-controlled, cross-over trial. *Proceedings:Biological Sciences, 270*, 2147–2150.

Redfern, M. S., Muller, M., Jennings, J. R., & Furman, J. M. (2002). Attentional dynamics in postural control during perturbations in young and older adults. *The Journals of Gerontology, A57*, B298.

Reimers, S., & Maylor, E. A. (2006). Gender effects on reaction time variability and trial-to-trial performance: Reply to Deary and Der (2005). *Aging, N europsychology, and Cognition, 13*, 479-489.

Reinberg, A., Bicakova-Rocher, A., Mechkouri, M, & Ashkenazi, I. (2002). Right- and left-brain hemisphere. Rhythm in reaction time to light signals is task-load-dependent: Age, gender, and handgrip strength rhythm comparisons. *Chronobiology International, 19*, 1087-1106.

Robinson, M. C., & Tamir, M. (2005). Neuroticism as mental noise: A relation between neuroticism and reaction time standard deviations. *Journal of Personality and Social Psychology, 89*, 107-115.

Rogers, M. W., Johnson, M. E., Martinez, K. M., Mille, M-L, & Hedman L. D. (2003). Step training improves the speed of voluntary step initiation in aging. *The Journals of Gerontology, A58*, 46-52.

Rose, S. A., Feldman, J. F., Jankowski, J. J., & Caro, D. M. (2002). A longitudinal study of visual expectation and reaction time in the first year of life. *Child Development,73*, 47.

Rosenbaum, D. A. (1991). *Human motor control*. California: Academic Press.

Rudisill, M., & Toole, T. (1992). The effects of a physical-activity program on reaction-time and movement time for the older adult. *Journal of Human Movement Studies, 22*, 205-212.

Sanders, A. F. (1998). *Elements of human performance: Reaction processes and attention in human skill.* New Jersey: Lawrence Erlbaum Associates.

Schmidt, R. A., & Wrisberg, C. A. (2000). *Motor learning and performance* (2nd ed.). Champaign, IL: Human Kinetics.

Schmidt, R. A., & Wrisberg, C. A. (2004). *Motor learning and performance* (3rd ed.). Champaign, IL: Human Kinetics.

Schweitzer, K. (2001). Preattentive processing and cognitive ability. *Intelligence, 29*, 169.

Scott, J. P. R., McNaughton, L. R., & Polman, R. C. J. (2006). Effects of sleep deprivation and exercise on cognitive, motor performance and mood. *Physiology & Behavior, 87*, 396-408.

Sheridan, M. R. (1981). Response programming and reaction time. *Journal of Motor Behavior, 13*, 161-176.

ShukittHale, B., Askew, E. W., & Lieberman, H. R. (1997). Effects of 30 days of undernutrition on reaction time, moods, and symptoms. *Physiology &Behavior, 62*, 783-789.

Shulman, B. B., Russell, S. C., & Rastatter, M. P. (1986). Syntactic decoding times of learning disabled children. *Perceptual and Motor Skills, 62*, 259-264.

Silverman, I. W. (2006). Sex differences in simple visual reaction time: A historical meta-analysis. *Sex Roles, 54*, 57-68.

Simonen, R. L., Videman, T., Battie, M. C., & Gibbons, L. E. (1998). The effect of lifelong exercise on psychomotor reaction time : A study of 38 pairs of male monozygotic twins. *Medicine and Science in Sports and Exercise, 30*, 1445-1450.

Singh, R., Pentland, B., Hunter, J., & Provan, F. (2007). Parkinson's disease and driving ability. *Journal of Neurology Neurosurgery and Psychiatry, 78*, 363-366.

Smith, A., Brice, C., Leach, A., Tilley, M, & Williamson, S. (2004). Effects of upper respiratory tract illnesses in a working population. *Ergonomics, 47*, 363-369.

Sparrow, W. A., Begg, R. K., & Parker, S. (2006). Aging effects on visual reaction time in a single task condition and when treadmill walking. *Motor Control, 10*, 201-211.

Strayer, D. L., & Kramer, A. F. (1990). Attentional requirements of automatic and controlled processing. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16*, 67-82.

Sung, E. J., Min, B. C., Kim, S. C., & Kim, C. J. (2005). Effects of oxygen concentrations on driver fatigue during simulated driving. *Applied Ergonomics, 36*, 25-31.

Surwillo, W. W. (1973). Choice reaction time and speed of information processing in old age. *Perceptual and Motor Skills,* 36, 321-322.

Szalmas, A., Bodrogi, P., & Sik-Lanyi, C. (2006). Characterizing luminous efficiency functions for a simulated mesopic night driving task based on reaction time. *Ophthalmic and Physiological Optics, 26*, 281-287.

Szinnai, G. H., Schachinger, M. J., Arnaud, L., Linder, & Keller, U. (2005). Effect of water deprivation on cognitive-motor performance in healthy men and women. *The American Journal of Physiology, 289*, 275-280.

Un, N., & Erbahçeci, F. (2001). The evaluation of reaction time on mentally retarded children. *Pediatric Rehabilitation, 4*, 17-20.

Takahashi, M., Nakata, A., Haratani, T., Ogawa, Y., & Arito, H. (2004). Post-lunch nap as a worksite intervention to promote alertness on the job. *Ergonomics, 47*, 1003-1013.

Taniguchi, Y. (1999). Effect of practice in bilateral and unilateral reaction-time tasks. *Perceptual and Motor Skills, 88*, 99-109.

Tsang, W. W. N., & Hui-Chan, C. W. Y. (2004). Effects of exercise on joint sense and balance in elderly men: Thai Chi versus golf. *Medicine and Science in Sports and Exrecise, 36*, 658-667.

Underwood, G. (2007). Visual attention and the transition from novice to advanced drivers. *Ergonomics, 50*, 1235-1249.

Van den Berg, J., & Neely, G.. (2006). Performance on a simple reaction time task while sleep deprived. *Perceptual and Motor Skills,102*, 589-600.

Watanabe, A., Kato, N., & Kato, T. (2002). Effects of creatine on mental fatigue and cerebral hemoglobin oxygenation. *Neuroscience Research, 42*, 279-285.

Welford, A. T. (1980). *Choice reaction time: Basic concepts.* New York: Academic Pres.

Woodworth, R. S., & Schlosberg, H. (1954). *Experimental Psychology*. New York: Henry Holt.

Xu, D. Q., Li, J. X., & Hong, Y. (2005). Effect of regular Tai Chi and jogging exercise on neuromuscular reaction in older people. *Age and Ageing, 34*, 439-444.

Yagi, Y., Coburn, K. L., Estes, K. M., & Arruda, J. E. (1999). Effects of aerobic exercise and gender on visual and auditory P300, reaction time, and accuracy. *European Journal of Physiology, 80*, 402-408.

Yeung, S. S., Au, A. L., & Chow, C. C. (1999). Effects of fatigue on the temporal neuromuscular control of vastus medialis muscle in humans. *European Journal of Applied Physiology, 80*, 379-385.

Zisi, V., Michalopoulou, M., Tzetzis, G., & Kioumourtzoglou, E. (2001). Effects of a short-term exercise program on motor function and whole body reaction time in the elderly. *Journal of Human Movement Studies, 40*, 145-160.

APPENDICES

APPENDIX A

INFORMED CONSENT

No:

GÖNÜLLÜ KATILIMCI FORMU

Bu çalışmanın amacı, reaksiyon zamanlarının cinsiyete göre oluşan farklarını azaltan etmenleri araştırmaktır. Reaksiyon zamanı cihazıyla yapacağınız test yaklaşık 10 dakikanızı alacaktır. Her denemenizde bir işitsel veya görsel uyaran gelecek ve toplamda 30 adet deneme yapılacaktır. Çalışmanın amacına ulaşabilmesi açısından uyaran geldiğinde hızlı bir şekilde tepki vermeniz çok önemlidir. Bu çalışmaya tamamen kendi isteğinizle katılıp katılmadığınızı sormak adına bu formu okumanız gerekmektedir. İstediğiniz an çalışmayı bırakma hakkına sahipsiniz. Katılımınızdan dolayı size fiziksel veya ruhsal bir zarar gelmeyecektir. Verilerin analizinde ve yazımında kimliğiniz kesinlikle geçmeyecektir. Veriler sadece bilimsel amaçla kullanılacak olup, araştırmacı tarafından saklanacaktır. Çalışmaya katıldığınız için çok teşekkür ederiz.

Adınız ve Soyadınız:
Tarih:
İmza:

✍ Aşağıdaki bilgileri doldurursanız seviniriz.

- Yaş:
  Cinsiyet: Kadın ….. Erkek …..
  Baskın el: Sağ ….. Sol …..
- Sürücü belgeniz var mı? Hayır ..... Evet ..... Cevabınız 'Evet' ise;
  a. Sürücü belgenizin sınıfı nedir? ……….
  b. Hangi yılda aldınız? ……….
  c. Düzenli olarak araç kullanıyor musunuz?
     Evet….. Ne kadar süredir? ……
     Hayır …..
  d. Yıllık ortalama km. : ……….
  e. Aylık ortalama km. : ……….

- Düzenli egzersiz/spor yapıyor musunuz? Hayır ..... Evet ..... Cevabınız 'Evet' ise;
    a. Branşınız nedir? :………………………………….
    b. Haftada kaç gün antrenman yapıyorsunuz? : ……..
    c. Günde kaç saat yapıyorsunuz?
    d. Kaç yıldır yapıyorsunuz?

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APPENDIX B

INFORMATION RECORDS SHEET

Name of The Group

	Female	Male
_01		
_02		
_03		
_04		
_05		
_06		
_07		
_08		
_09		
_10		
_11		
_12		
_13		
_14		
_15		
_16		
_17		
_18		
_19		
_20		

APPENDIX C

DATA CODING FORM

Participant Number:

	RIGHT			LEFT		
	1	2	3	1	2	3
SVRT						
SVRT-M						
TCRT						
ThrCRT						

Participant Number:

	RIGHT			LEFT		
	1	2	3	1	2	3
SVRT						
SVRT-M						
TCRT						
ThrCRT						

Participant Number:

	RIGHT			LEFT		
	1	2	3	1	2	3
SVRT						
SVRT-M						
TCRT						
ThrCRT						

Note: SVRT: Simple Visual Reaction Time, SVRT-M: Simple Visual Reaction Time with Movement, TCRT: Two Choice Reaction Time, ThrCRT: Three Choice Reaction Time