SPORMETRE
The Journal of Physical Education and Sport Sciences
Beden Eğitimi ve Spor Bilimleri Dergisi

DOI: 10.33689/spormetre.1024364

Geliş Tarihi (Received): 16.11.2021 Kabul Tarihi (Accepted): 24.06.2022 Online Yayın Tarihi (Published): 30.06.2022

COMPARISON OF MENTAL ROTATION AND REACTION TIME PERFORMANCES IN DEAF ATHLETES AND NON-ATHLETES

Ali Kamil Güngör[1*], Şenay Şahin[1]
[1]Bursa Uludağ Üniversitesi, Spor Bilimleri Fakültesi, Bursa

Abstract: The coordination of perceptual-cognitive and motor processes is one of the main components determining sports performance. However, many factors affect these components, such as disability, gender, doing sport, etc. The aim of this study is to determine the mental rotation and reaction time performance of deaf athletes and non-athletes in terms of doing sport and gender. 42 heavy hearing impaired (90+ dB) students, 22 males, and 20 females, participated in the study. 22 of the participants were deaf basketball athletes, and 20 were deaf non-athletes. The participants' mental rotation and reaction time performance measurement tests were carried out with a computer-based software MP36 (Biopac System, USA). Independent Samples T-test and (multivariate) Manova tests were performed to evaluate the data. There were no statistically significant differences between the groups, neither mental rotation nor reaction time variables, in terms of doing sport. However, there were statistically significant differences between the groups in both mental rotation and reaction time variables regarding gender and doing sport. As a result, it was found that male athletes are better than women who are not athletes in some of the mental rotation and reaction time variables. Another important result was no significant difference in both mental rotation and reaction time variables between deaf male non-athletes and female non-athletes. As a result, it is suggested that doing sports improves both the mental rotation and reaction time of deaf male athletes.

Key Words: Doing Sport, Deaf, Mental Rotation, Reaction Time, Gender Differences

SPOR YAPAN VE YAPMAYAN İŞİTME ENGELLİLERİN MENTAL ROTASYON VE REAKSİYON ZAMANI PERFORMANSLARININ KARŞILAŞTIRILMASI

Öz: Algısal-bilişsel ve motor süreçlerin koordinasyonu sporda performansı belirleyen ana bileşenlerdendir. Ancak bu bileşenleri etkileyen engellilik, cinsiyet, spora yapma vb. birçok faktör bulunmaktadır. Bu çalışmanın amacı, sporcu ve sedanter işitme engellilerin mental rotasyon ve raksiyon zamanı performanslarını spora yapma ve cinsiyet açısından belirlemektir. Çalışmaya 22'si erkek, 20'si kız toplam 42 ağır işitme engelli (90+ dB) öğrenci katılmıştır. Katılımcıların 22'si işitme engelli basketbolcu, 20'si ise işitme engelli sedanter bireylerden oluşmuştur. Katılımcıların hem mental rotasyon hem de reaksiyon zamanı performans ölçüm testleri bilgisayar tabanlı bir yazılım olan MP36 (Biopac System, ABD) ile yapılmıştır. Verileri değerlendirmek için Bağımsız Örneklemler T testi ve (çok değişkenli) Manova testleri uygulanmıştır. Gruplar arasında hem mental rotasyon hem de reaksiyon zamanı değişkenleri arasında spora yapma açısından istatistiksel olarak anlamlı fark bulunmamıştır. Ancak cinsiyet ve spor açısından hem mental rotasyon hem de reaksiyon zamanı değişkenlerinde gruplar arasında istatistiksel olarak anlamlı farklılıklar olduğu tespit edilmiştir. Sonuç olarak bazı mental rotasyon ve reaksiyon zamanı değişkenlerinde erkek sporcuların sporcu olmayan kadınlara göre daha iyi olduğu belirlenmiştir. Bir diğer önemli sonuç, işitme engelli sedanter erkek ve sedanter kadın arasında hem mental rotasyon hem de reaksiyon zamanı değişkenlerinde istatistiksel olarak anlamlı bir farklılık bulunmamıştır. Sonuç olarak, spor yapmanın işitme engelli erkek sporcuların hem mental rotasyonunu hem de reaksiyon süresini iyileştirdiğini düşündürmektedir.

Anahtar Kelimeler: Spor yapma, İşitme Engelli, Mental Rotasyon, Reaksiyon Zamanı, Cinsiyet Farklılıkları

INTRODUCTION

* *Sorumlu Yazar: Ali Kamil Güngör, Araştırma Görevlisi, E-mail: alikamilgungor@uludag.edu.tr*

Sports professionals have studied perceptual-cognitive skills, such as attention skills (Memmert, 2006), memory performance (Williams et al., 1993), and visual search behavior (Mann et al., 2007), to develop cognitive skills associated with sports performance. In a meta-analysis study related to sports sciences, it was stated that there was a positive correlation between cognitive and motor functions (Etnier, 2006). Stated this correlation, motor development, and movement practice are confirmed by the certain assumption (Diamond, 2007) that factors are related to cognitive performance, particularly spatial ability (Campos et al., 2000). Indeed, The athletes constantly develop their spatial information to locate their partners or competitors (team sport), define the target location (ball trap, shooting, golf), and find landmarks in space (track and field, gymnastics). Consequently, sports practice supports the enriched experience of the spatial process. According to the environmentalist model (Lohman and Nichols, 1990), the practice of spatial activities would change the individual spatial capacity since the situations which are confronted, and a person would develop the cognitive processes required by those activities. Spatial abilities are defined as cognitive processes that include orientation, visualization, and mental rotation (Linn and Peterson 1985). Nowadays, the mental rotation appears to be the best-studied component of these one's visual-spatial abilities. However, Watt (1991) stated that due to the problem in the ear of the hearing impaired individual, they are insufficient in directing visual movements and spatial orientation. It has been hypothesized that the integrity of the senses to each other is impaired due to the deafness of the hearing-impaired and that the lack of hearing causes another sense to take on a greater task and accordingly leads to its further development (Watt, 1991; Tharpe et al., 2002; Pérez-Tejero, 2011). In line with these assumptions, it has not yet been clarified how doing sport affects the mental rotation and reaction time of hearing impaired individuals regarding perceptual-cognitive processes.

Mental rotation is a certain visuospatial ability that involves the process of imagining how a two- or three-dimensional object would look if rotated away from its original upright position (Shepard and Metzler, 1971). However, it is surprising that the connection between different kinds of sports activities and mental rotation performance has sustained little pay attention so far. Few studies examined the relationship between sports activity and mental rotation performance (Ozel et al., 2002; Jansen and Pietsch 2010; Moreau et al., 2011; Jansen et al., 2012;). Lately, Jansen et al., (2012) showed that football players perform more advanced mental rotation in their chronometric mental rotation tasks compared to non-athletes. In another study, Moreau et al., (2011) also reported that the professional athletes who experienced the daily practice of a combat sport (wrestling, judo, fencing) had better mental rotation performance than the professional runners. Jansen and Pietsch (2010) stated that the mental rotation performance of the experimental group increased after attending a 45-minute sports practice class, while the control group did not increase their visual-spatial performance after listening to a class. With these findings, the neuroscience researchers have indicated that after juggling exercise, there is a rise in gray matter densities in the intraparietal sulcus (Draganski et al., 2004), which is one of the activated zones of the brain throughout a mental rotation tasks (Jordan et al., 2002; jancke et al., (2009). This result suggests that sports activities (juggling, football, golf, wrestling ect) that contain highly coordinative and rotational movement directions related to motor processes improve mental rotation performance.

Mental rotation ability repeatedly has been shown to exhibit one of the largest gender biases reported in the cognitive literatüre; Linn and Peterson (1985) found an effect size of *d* 0.73 (from 62 studies) favoring males of all ages on mental rotation tasks. Voyer et al. (1995) also found an overall effect size of *d* 0.56 for all ages (from 78 studies) and, like Linn and Peterson

(1985), also found the largest difference favoring males was in the adult (over age 18) group at *d* 0.66), especially on the mental rotation task of Vandenberg and Kuse (1978). Voyer and Isaacs (1993) suggested that an important relationship exists between gender and the amount of sports activities, and they speculated that more extensive practice in women would reduce the magnitude of the gender difference in the mental rotation test. It was stated in the above studies that sports activities and sign language have a positive effect on mental rotation performance. However, as we have investigated, there were no studies evaluating the mental rotation performance of deaf athletes and non-athletes in terms of doing sports and gender differences in the literature.

Reaction time is another important parameter related to cognitive and motor processes in sports performance and mental rotation tasks. The reaction time is defined as the elapsed time between the start of a stimulus and the motor response (Reina et al., 2007). Taylor & Campbell (1976) claim that a sudden unexpected auditory orientation speeds up, in connection with reaction time, the visual stimulation process in terms of the subject on which it focuses. Similar information is not existing for the hearing impaired because of the absence of hearing can increase the reaction time and hinder the ability to focus on a target outside the visual field (Gkouvatzi et al., 2010). Compensatory plasticity holds that the lack of auditory stimulation experienced by deaf individuals is met by enhancements in visual cognition. However, reports in the educational and cochlear implant literature document deficient visual cognition in deaf individuals. This discrepancy is probably due to the complex etiology of deafness. When free from various confounding factors, deafness per se is seen to shift the spatial distribution of attention such that attention to the peripheral visual field, but not the central visual field, is heightened. Neville & Lawson (1987) showed that Deaf individuals performed faster and better than non-deaf controls when asked to detect the direction of motion of a peripheral target at an attended location. Savelsbergh & Netelendos (1992) conducted a study aimed at examining whether visual orientation problems affect motor development in deaf persons. Deaf persons had longer reaction times than non-deaf ones for targets outside their visual field (125º), while no differences were found for targets inside their visual field (40º). No differences were noted between deaf and hard-of-hearing during the tests that were conducted. On the other hand, several studies show that persons with hearing impairment have greater visual acuity than those with non-deaf (Sladen et al., 2005; Gkouvatzi et al., 2010). As stated above, Savelsbergh & Netelendos (1992) did not find any difference in reaction time between deaf and hard-hearing individuals.

As far as we have investigated, no study has been reached that evaluates the reaction time performance of deaf athletes and non-athletes in terms of gender differences and doing sport in the literature. It is important to know how doing sport affects mental rotation and reaction time performance of deaf athletes and non-athletes to guide the development of visuospatial cognitive and motor processes in doing sport. The aim of the study is to determine the mental rotation and reaction time performance of deaf athletes and non-athletes in terms of doing sport and gender. We hypothesize that mental rotation and reaction time performances of deaf athletes are better than those of non-athletes.

METHOD

Only students with hearing impairment participated in the study, and 29 of 71 deaf students were not included because they had other disabilities such as being blind and mentally retarded. The study was conducted by the principles of the Helsinki Declaration and was confirmed (2019-17/11) by the local ethics committee for human experiments at Bursa Uludağ University.

Research Model
A survey-type research model, one of the quantitative research methods, was used. In this model, independent variables are not manipulated (Can, 2014). Participants were compared according to their sports status and gender.

Research Group
The universe of the research consists of students with heavy hearing impairment (90+ dB) in Bursa. The sample consists of a total of 42 deaf students, twenty-two males (mean age = 18±1.19 years) and twenty females (mean age = 17.85±1.38 years), who studied at Nilüfer Private Education Vocational High School in Bursa participated in the study voluntarily. Their families signed a voluntary consent form. Participants were randomly divided into four groups in terms of doing sport and gender. 11 males and 11 females were amateur basketball players, and 11 males and 9 females were non-athletes. The mental rotation and reaction time performances of the participants were compared.

Procedure
The study was conducted at Nilüfer Private Education Vocational High School in Bursa. The study was carried out in groups of 10-11 on Tuesdays and Thursdays, between 10:00 and 12:00 on weekdays, in a quiet room where conditions such as lighting, humidity, etc., are suitable. The study was completed in 5 non-consecutive days. The participants were informed about the study on the first day, and all participants made application trials. On other days, real practice tests were conducted. Each participant was taken to the room one by one. The participants first applied the computer-based mental rotation test, which lasted for 5 minutes. Then 2 minutes rest was given. Following that, they applied computer-based reaction time tests, which took about 5 minutes. No second try was given in the tests. A staff member who knew sign language also explained the procedure to the participants during the whole process. Inclusion criteria to study; Deaf who knew sign language, Heavy hearing loss (90+ dB), Being between 17-22 years old, Not having any disabled other than hearing impairment (e.g., mentally retarded, blind), Playing basketball for actively at least two years in terms of doing sport participants. The coach of the doing sports group also stated that they do basketball training three days a week. Detailed information about the application of the tests is explained below.

Data Collection Tools
Mental rotation test: In the study, ımage files containing three-dimensional cube figures created by Shepard and Metzler (1971) of the "Mental Rotation Stimulus Library" library prepared by Peters and Battista (2008) were used in the computer-based MP36 (Biopac System, USA) mental rotation test. These images were created by adding 10 cubes end to end. The pictures consist of 3-dimensional images of the cubes rotated at certain angles in 3-dimensional space (figure1), and the test consisted of a total of 16 question sets. Each question contained four images, and the first image was the reference image (figure1). Only one of the other 3 pictures is the same as the object in the "reference" picture, and the only difference is that it is rotated in 3-dimensional space. Image for the first 8 questions, the X-axis was rotating in the direction, while the last 8 questions were rotating in the Y-axis direction. For both axes, the "angle of rotation" has occurred in 30^0 increments between $0\text{-}180^0$. The participant was asked to find out which of the three pictures is the same as the reference picture as soon as possible. The response time was measured by the computer in milliseconds (ms) with the record of "correct," "wrong," and "error process" and stored on the computer. The total duration of the test was 5 minutes, and the participants completed the test as soon as possible by finding the correct picture and pressing the press button. All participants used their dominant hand.

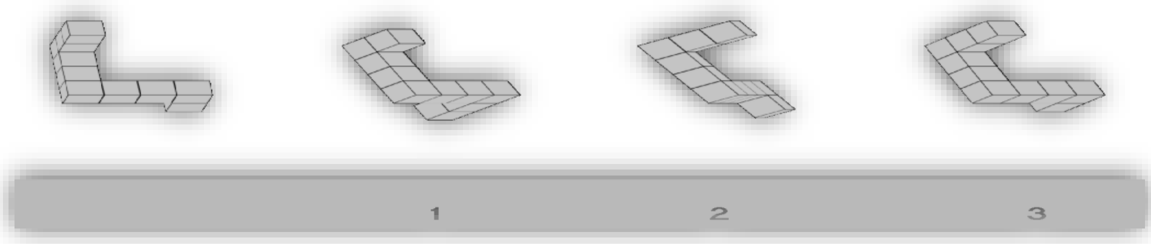


Figure 1. A set of questions was prepared with pictures selected from the "Mental Rotation Stimulus Library" library by Peters and Battista 2008.

Reaction time test: Visual reaction time (VRT) test was performed using a computer-based system MP36 (Biopac System, USA). This system is software that includes mental rotation, visual and auditory reaction, and finger beat tests. As soon as participants saw the successive red square (10 in total) with fixed time intervals (fix) of 7x7 cm in size on the VRT computer screen, they were asked to press the button '1' as fast as possible. The same test was performed at random intervals. For the selected visual reaction test, any of the red, yellow, blue, green, and black colors come with fixed time intervals. The participants were asked to press the "1" button as soon as they saw the red square and the "2" button when they saw one of the other colors. The same test was performed at random intervals. All the answers given by the participant by pressing the button were recorded by the computer in milliseconds. All participants used their dominant hand.

Analysis of Data

The analysis of the data obtained in the study was done in a computer environment using the SPSS v.23 statistics program. With the Kolmogorov-Smirnov Test, it was examined whether the data were suitable for normal distribution. It is determined that the data show normal distribution. İndipendent samples t-test and (multivariate) Manova tests were performed to evaluate the data. Binary comparisons were determined with the Bonferroni test. The Effect Size Cohen’s d was calculated, which was considered as large above 0.8, the medium between 0.8 and 0.5, small between 0.5 and 0.2, and trivial lower than 0.2. Descriptive statistics for variables are stated as the arithmetic mean, and standard deviation (SD), and the level of significance was set at $p < 0.05$.

RESULTS

The age, body height, body weight, weighted secondary education achievement score (WSEAS) of deaf male and female athletes and deaf male and female non-athletes were ages 18,3±1,4, 17,6±0,8, 18,4±1,5, 17,1±0,7; heights 174,3±6,5, 169,6±4,1, 156,1±3,8, 159,2±4,8; weights 68.1±15.8, 66.7±8.1, 54.1±10.2, 58.8±6.2; WSAES 83.1±8.9, 83.7±12.1, 88.1±8.1, 82.5±8.2 respectively. Weighted secondary education achievement score is evaluated by over a hundred. The sports experience of deaf male and female athletes was 2.7±0.9 and 2.5±0.6 years, respectively. Table 1 shows the mental rotation and reaction time performance statistical results of deaf athletes and non-athletes with the independent sample T-test. Table 2 shows the mental rotation and reaction time performance statistical results of deaf athletes and non-athletes in terms of gender with the Manova test. Figure 2 shows the average mental rotation and reaction time performance of deaf athletes and non-athletes with regard to gender.

Table 1. The comparison of mental rotation and reaction time performance with regard to doing sport

Variables	Deaf	n	Mean±S.D	t	p	Cohen's d
Mental rotation correct number	Athletes	22	8,1±2,1	1,683	0,099	0.57
	Non-athletes	20	6,95±1,9			
Mental rotation time	Athletes	22	129,5±54,7	-,145	0,886	0,04
	Non-athletes	20	132,1±59,3			
Simple visual reaction time fixed ınterval	Athletes	22	311,7±73,8	-1,326	0,193	0.41
	Non-athletes	20	347,8±99,4			
Simple visual reaction time random ınterval	Athletes	22	314,2±61,7	-1,809	0,079	0.56
	Non-athletes	20	353,1±75,9			
Complex visual reaction time fixed ınterval	Athletes	22	450,7±99,8	-1,752	0,088	0.54
	Non-athletes	20	507,1±108,1			
Complex visual reaction time random ınterval	Athletes	22	460,3±80,1	-1,367	0,181	0.43
	Non-athletes	20	506,9±131,6			

As shown in table 1, there was no significant difference between the groups for any variables. But mental rotation correct number, simple visual reaction time random ınterval and complex visual reaction time fixed ınterval had medium effect size (*d*=0.57, *d*=0.56, *d*=0.54) respectively. Simple visual reaction time fixed ınterval and complex visual reaction time random ınterval had small effect sizes (*d*=0.41, *d*=0.43), respectively. On the other hand, mental reaction time had a trivial effect size (*d*=0.04).

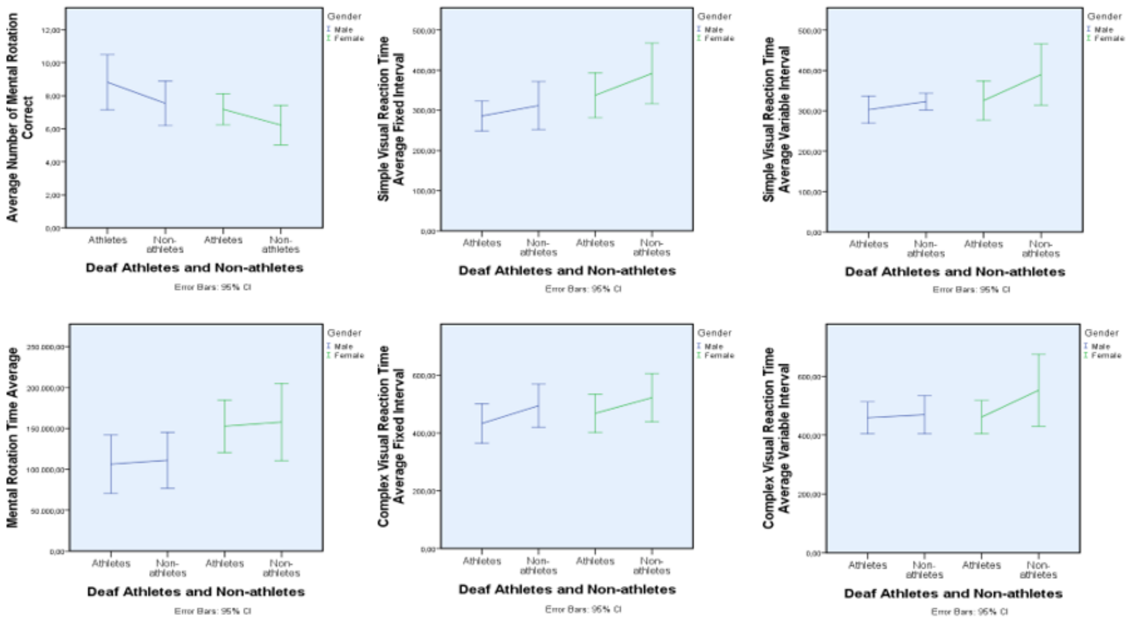
Table 2. The comparison of mental rotation and reaction time performance in terms of doing sports and gender

Variables	Deaf Athletes		Deaf Non-athletes					
	Male (1) (n:11) Mean±S.D	Female (2) (n:11) Mean±S.D	Male (3) (n:11) Mean±S.D	Female (4) (n:9) Mean±S.D	F	p	Post hoc	Cohen d
Mental rotation correct number	8.8±2.4	7.1±1.4	7.5±2.1	6.2±1.5	3,12	0,03*	1-4*	0.99
Mental rotation time	106.3±53.5	152.7±47.1	111.1±50.1	157.7±61.4	2,68	0,06		0.92
Simple visual reaction time fixed ınterval	285.9±55.3	337.5±83.2	311.8±88.9	391.8±98.1	2,96	0,04*	1-4*	0.96
Simple visual reaction time random ınterval	302.9±50.1	325.5±72.2	322.9±30.7	389.9±98.6	3,14	0,03*	1-4*	0.99
Complex visual reaction time fixed ınterval	433.2±99.2	468.2±99.1	494.6±111	522.4±108.5	1,32	0,28		0.64
Complex visual reaction time random ınterval	459.2±80.5	461.5±83.6	469.5±96.3	522.5±159.1	1,67	0,18		0.72

*Significance level was accepted as p<0.05

As shown in table 2, The multivariate Manova comparing the mental rotation correct number, simple visual reaction time fixed ınterval and simple visual reaction time random ınterval between deaf athletes and non-athletes in terms of gender showed significant results (F=3,12, p<0.03, d= 0.99), (F=2.96, p<0.04 d= 0.96), (F=3,14, p<0.03, d= 0.99) respectively. The effect size was determined to be large in all three variables. In the multiple comparisons of the Bonferroni test, deaf male athletes were significantly different from deaf non-athletes female

in all three variables p<0.05. However, no significant difference was found in the comparison between other gender groups for athletes and non-athletes p>0.05.
The multivariate Manova comparing the mental rotation time, complex visual reaction time fixed ınterval and complex visual reaction time random ınterval between deaf athletes and non-athletes in terms of gender did not show significant results (F=2,68, p>0.06, d= 0.), (F=1.32, p>0.28 d= 0.96), (F=3,14, p<0.03, *d*= 0.99) respectively. But while the effect size was large (d=0.92) in terms of the mental rotation time, complex reaction time fixed interval and complex reaction time random intervals were medium (d=0.72, d=0.64), respectively. In the multiple comparisons of the Bonferroni test, there were no significant differences between gender groups for athletes and non-athletes p>0.05.



Figures 2. Mental rotation and reaction time performance averages of the groups in terms of gender and sport.

DISCUSSION AND CONCLUSION

The present study indicated the relation between mental rotation and reaction time variables with doing sports in deaf athletes and non-athletes. The main findings of this study; ı) Male athletes had better mental rotation correct number, simple visual reaction time variables than deaf female non-athletes. ıı) No significant difference between both deaf athletes and non-athletes groups, neither in the process of mental rotation variables nor in the process of reaction times variables. The findings of the study are important because the metal rotation and reaction time performances of deaf athletes and non-athletes in terms of doing sport and gender were investigated for the first time with the current study.

In studies that investigated mental rotation and sports (football, gymnastics, wrestling, running), physical activity which, both acute and chronic, was found to be positively associated with mental rotation performance (Ozel et al., 2002). In these studies, athletes showed a significantly higher mental rotation performance than non-athletes. In the present study, the gender of deaf athletes and non-athlete groups were mixed in terms of gender. Studies put forward an appreciable effect size supporting males over females on mental rotation tasks (Linn and Peterson 1985; Voyer et al. 1995). However, there is uncertainty about how doing sport affects mental rotation in terms of gender, especially for females. Although Scali et al. (2000) and Masters (1998) reported that sports-related experiences did not have a facilitating effect on scores of the female in mental rotation tasks; Ozel et al., (2002) and Voyer, et al. (2000) reported that such experiences had a facilitating effect on scores of female. The fact that deaf males and females are in the mixed group may be seen as a limitation, but we thought that deaf females who do sport may have improved mental rotation and reaction time performances.

We found that deaf athletes and non-athletes are significantly different in terms of gender, especially favoring male athletes. Male athletes had better mental rotation correct numbers than deaf female non-athletes. Schmidt et al. (2016) examined the mental rotation performance of gymnasts, orienteers, and sedentary individuals and reported that men showed better mental rotation performance than women. Pietsch and Jansen (2012a) examined the relationship between mental rotation and motor coordination skills of university women and men and found that mental rotation skills of male university students were better than female students. Our results were presumably in the expectation that males are better. The male and female might use different strategies when responding to the mental rotations tasks. For example, Bosco et al., (2004) report that males and females use different cognitive strategies when solving problems requiring the use of spatial abilities. Men are more likely to guess which choice matches the target (Voyer and Saunders, 2004), whereas women only guess when time limits for responding are removed (Voyer, Rodgers, and McCormick, 2004).

Jordan et al. (2002) discussed that different points of the brain are activated in the mental rotation tasks of men and women and that women spend more time and effort adjusting the identity of visual objects in solving spatial problems. Kucian et al. (2005) and Thomsen et al. (2000) stated that they had similar results. But an important finding in the present study was that there was no significant difference between deaf male and female non-athletes in terms of mental rotation variables. There is important evidence that deaf and non-deaf who know sign language perform better in mental rotation tasks than those who do not know sign language (Emmorey et al., 1993; Talbot and Haude, 1993; Emmorey et al., 1998; Keehner and Gathercole, 2007). Talbot and Haude (1993), tested three different groups based on their experience in sign language, and they found that experience in sign language was related to success in the rotation tests. The more experienced the subjects are in sign language, the higher the result achieved in the rotation tests. The deaf and non-deaf sign language users were better able to generate complex images faster than non-deaf and non-signers, suggesting enhanced complex mental imagery/rotation abilities. Sign language grammatical structure thus seems to require the use of mental imagery/rotation, which can lead to skill enhancements (Goodman, 2015). In the present study, it was found that male athletes have better mental rotation than female non-athletes. However, there was no significant difference between male athletes and male non-athletes also female athletes and male non-athletes. These results made us think that besides knowing sign language, doing sport is better than women in mental rotation tasks in favor of men.

Another important finding was the reaction time results that deaf male athletes were better than deaf female non-athletes in the fixed and random interval of simple reaction time. Gender is one of the factors affecting visual reaction time performance (Schmidt & Lee, 1988; Gursoy, 2010). Dane & Erzurumluoglu (2003) reported that the hand-eye of male reaction time performance is shorter than females. Sotorey et al., (2014) stated that gender differences were statistically significant and that men were shorter at the reaction time than women. Eskicioğlu and Çoknaz (2016) compared the visual reaction times of deaf individuals who do sport in different branches and deaf individuals who do not, and it was found that the visual reaction times of deaf individuals who do sport are shorter than those who do not sport. Dane & Erzurumluoglu (2003) reports that the physical measurement of the body, such as height, weight, muscle strength, and lung function, affects the reaction time and also claim that such gender differences are associated with bodily measurements were most likely based on gender-related endocrine differences. Fine et al. (2005) stated that the advantage of reaction time in profoundly deaf adults is due to the flexibility of the cross-modality in the auditory cortex that responds to the sign language and the immersion of the deaf in a completely visual language affects these regions. However, they reported that the flexibility of cross-modality was not available to individuals who are not profoundly deaf or non-deaf signers. In the present study, the reason why there was no significant difference between deaf male and female non-athletes could be actively using sign language. However, there is a significant difference between male athletes and female non-athletes in terms of simple reaction time variables, and the absence of a significant difference between male athletes and female athletes considered that doing sport positively affects the reaction time of male and female athletes.

The limitations of the present study are the exclusion of non-deaf individuals, the low number of participants, the evaluation of both congenital deafness and deafness acquisition after birth (up to 4 years old) together, and the lack of a test-retest method.

As a result, there was no significant difference between deaf athletes and non-athletes in terms of both mental rotation and reaction time variables. It was determined that deaf male athletes were statistically better in the correct number of mental rotation and simple visual reaction variables than deaf female non-athletes with regard to gender. Further studies with experimental and more participants are needed to confirm these results.

Conflict of interest
The authors declare no competing interest and specific funding from grant agencies to support this study. The results of the study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation.

REFERENCES

Bosco, A., Longoni, A. M., Vecchi, T. (2004). Gender effects in spatial orientation: Cognitive profiles and mental strategies. *Applied Cognitive Psychology: The Official Journal of the Society for Applied Research in Memory and Cognition*, *18*(5), 519-532.

Can, A. (2014). Bilimsel araştırma sürecinde nicel veri analizi. Pegem akademi,2. Baskı. Ankara

Campos, J. J., Anderson, D. I., Barbu-Roth, M. A., Hubbard, E. M., Hertenstein, M. J., Witherington, D. (2000). Travel broadens the mind. *Infancy*, *1*(2), 149-219.

Dane, S., Erzurumluoglu, A. (2003). Sex and handedness differences in eye-hand visual reaction times in handball players. *International Journal of Neuroscience*, *113*(7), 923-929.

Diamond, A. (2007). Interrelated and interdependent. *Developmental science*, *10*(1), 152-158.

Draganski, B., Gaser, C., Busch, V., Schuierer, G., Bogdahn, U., May, A. (2004). Changes in grey matter induced by training. *Nature*, *427*(6972), 311-312.

Emmorey, K., Klima, E., Hickok, G. (1998). Mental rotation within linguistic and non-linguistic domains in users of American sign language. *Cognition*, *68*(3), 221-246.

Eskicioğlu Y. E., Çoknaz, H. (2016). Türkiye'de Futbol, Türk Halkoyunları, Basketbol Ve Voleybol Antrenmanlarına Katılan ve Katılmayan İşitme Engelli Bireylerin Görsel Reaksiyon Sürelerinin Karşılaştırılması. *İnönü Üniversitesi Beden Eğitimi ve Spor Bilimleri Dergisi*, 3(2), 18-25

Etnier, J. L., Nowell, P. M., Landers, D. M., Sibley, B. A. (2006). A meta-regression to examine the relationship between aerobic fitness and cognitive performance. *Brain research reviews*, *52*(1), 119-130.

Fine, I., Finney, E. M., Boynton, G. M., Anddobkins, K. R. (2005). Comparing The Effects of Auditory Deprivation and Sign Language Within The Auditory and Visualcortex. *J.Cogn.Neurosci.* 17.1621–1637.

Goodman, E. (2015). *Gender effects in cognition exist in deaf signers: New considerations for an old question* (Doctoral dissertation, Gallaudet University).

Gursoy, R. (2010). Sex differences in relations of muscle power, lung function, and reaction time in athletes. *Perceptual and motor skills*, *110*(3), 714-720.

Gkouvatzi, A. N., Mantis, K., Kambas, A. (2010). Comparative Study of Motor Performance of Deaf and Hard of Hearing Students in Reaction Time, Visual-Motor Control and Upper Limb Speed and Dexterity Abilities. *International Journal of Special Education*, *25*(2), 15-25.

Jäncke, L., Koeneke, S., Hoppe, A., Rominger, C., and Hänggi, J. (2009). The architecture of the golfer's brain. *PloS one*, *4*(3), e4785.

Jansen, P., Pietsch, S. (2010). Physical Activity improves mental rotation performance. *Creative Education*, *1*(1), 58-61.

Jansen, P., Lehmann, J., Van Doren, J. (2012). Mental rotation performance in male soccer players. *PloS one*, *7*(10), e48620.

Jordan, K., Wüstenberg, T., Heinze, H. J., Peters, M., Jäncke, L. (2002). Women and men exhibit different cortical activation patterns during mental rotation tasks. *Neuropsychologia*, *40*(13), 2397-2408.

Keehner, M., Gathercole, S. E. (2007). Cognitive adaptations arising from nonnative experience of sign language in hearing adults. *Memory and Cognition*, *35*(4), 752-761.

Kucian, K., Loenneker, T., Dietrich, T., Martin, E., Von Aster, M. (2005). Gender differences in brain activation patterns during mental rotation and number related cognitive tasks. *Psychology Science*, *47*(1), 112.

Linn, M. C., Petersen, A. C. (1985). Emergence and characterization of sex differences in spatial ability: A meta-analysis. *Child development*, 1479-1498.

Lohman, D. F., Nichols, P. D. (1990). Training spatial abilities: Effects of practice on rotation and synthesis tasks. *Learning and Individual Differences*, *2*(1), 67-93.

Mann, D. T., Williams, A. M., Ward, P., Janelle, C. M. (2007). Perceptual-cognitive expertise in sport: A meta-analysis. *Journal of Sport and Exercise Psychology*, *29*(4), 457-478.

Masters, M. S. (1998). The gender difference on the mental rotations test is not due to performance factors. *Memory and cognition*, *26*(3), 444-448.

Memmert, D. (2006). The effects of eye movements, age, and expertise on inattentional blindness. *Consciousness and cognition*, *15*(3), 620-627.

Moreau, D., Mansy-Dannay, A., Clerc, J., Guerrien, A. (2011). Spatial ability and motor performance: assessing mental rotation processes in elite and novice athletes. *International Journal of Sport Psychology*.

Neville, H. J., & Lawson, D. (1987). Attention To Central And Peripheral Visual Space İn A Movement Detection Task: An Event-Related Potential And Behavioral Study. Congenitally Deaf Adults. *Brain Research*, *405*(2), 268-283.

Ozel, S., Larue, J., Molinaro, C. (2002). Relation between sport activity and mental rotation: Comparison of three groups of subjects. *Perceptual and Motor Skills*, *95*(3_suppl), 1141-1154.

Pérez-Tejero J., Soto-Rey J., Rojo-González J. J. (2011). Study Of Reaction Time To Visual And Auditory Stimuli. Motricidad: *European Journal Of Human Movement*, 27, 149 – 162.

Peters, M., Battista, C. (2008). Applications of mental rotation figures of the Shepard and Metzler type and description of a mental rotation stimulus library. *Brain and cognition*, *66*(3), 260-264.

Pietsch, S., Jansen, P. (2012, August). The relationship between coordination skill and mental rotation ability. In *International Conference on Spatial Cognition* (pp. 173-181). Springer, Berlin, Heidelberg.

Reina, R., Moreno, F. J., Sanz, D. (2007). Visual behavior and motor responses of novice and experienced wheelchair tennis players relative to the service return. *Adapted physical activity quarterly*, *24*(3), 254-271.

Savelsbergh, G. J., Netelenbos, J. B. (1992). Can the developmental lag in motor abilities of deaf children be partly attributed to localization problems?. *Adapted Physical Activity Quarterly*, *9*(4), 343-352.

Shepard, R. N., Metzler, J. (1971). Mental rotation of three-dimensional objects. *Science*, *171*(3972), 701-703.

Soto-Rey, J., Pérez-Tejero, J., Rojo-González, J. J., Reina, R. (2014). Study of reaction time to visual stimuli in athletes with and without a hearing impairment. *Perceptual and motor skills*, *119*(1), 123-132.

Scali, R. M., Brownlow, S., Hicks, J. L. (2000). Gender differences in spatial task performance as a function of speed or accuracy orientation. *Sex roles*, *43*(5), 359-376.

Schmidt, R. A., Lee, T. D. (1988). Motor learning and control: A behavioral emphasis Champaign. *IL: Human Kinetics*.

Schmidt, M., Egger, F., Kieliger, M., Rubeli, B., and Schüler, J. (2016). Gymnasts and orienteers display better mental rotation performance than non-athletes. *Journal of individual differences*.

Sladen, D. P., Tharpe, A. M., Ashmead, D. H., Grantham, D. W., & Chun, M. M. (2005). Visual Attention İn Deaf And Normal Hearing Adults. *Journal Of Speech, Language, And Hearing Research*. vol. 48, pp.1529-1537.

Talbot, K. F., Haude, R. H. (1993). The relation between sign language skill and spatial visualization ability: Mental rotation of three-dimensional objects. *Perceptual and Motor Skills*, *77*(3_suppl), 1387-1391.

Taylor, R. L., Campbell, G. T. (1976). Sensory interaction: Vision is modulated by hearing. *Perception, 5*(4), 467-477.

Tharpe A. M., Ashmead D. H., Rothpletz A. M. (2002). Visual Attention in Children With Hearing Aids and Children With Cochlear İmplants. *Journal of Speech, Language and Hearing Research*. vol.445, 409-413.

Thomsen, T., Hugdahl, K., Ersland, L., Barndon, R., Lundervold, A., Smievoll, A. I., Sundberg, H. (2000). Functional magnetic resonance imaging (fMRI) study of sex differences in a mental rotation task. *Medical Science Monitor*, *6*(6), 1186-1196.

Vandenberg, S. G., Kuse, A. R. (1978). Mental rotations, a group test of three-dimensional spatial visualization. *Perceptual and motor skills*, *47*(2), 599-604.

Voyer, D., Isaacs, M. (1993). Sex differences in mental rotation: Role of practice and experience. In *Poster presented at the third meeting of the Canadian Society for Brain, Behavior, and Cognitive Science, Toronto, Ontario*.

Voyer, D., Voyer, S., Bryden, M. P. (1995). Magnitude of sex differences in spatial abilities: a meta-analysis and consideration of critical variables. *Psychological bulletin*, *117*(2), 250.

Voyer, D., Nolan, C., Voyer, S. (2000). The relation between experience and spatial performance in men and women. *Sex Roles*, *43*(11), 891-915.

Voyer, D., Saunders, K. A. (2004). Gender differences on the mental rotations test: a factor analysis. *Acta Psychologica*, *117*(1), 79-94.

Voyer, D., Rodgers, M. A., McCormick, P. A. (2004). Timing conditions and the magnitude of gender differences on the Mental Rotations Test. *Memory and cognition*, *32*(1), 72-82.

Watt J., Davis F. E. (1991). The prevalence of boredom proneness and depression among profoundly deaf residential school adolescents. American Annals of the Deaf, 136(5), 409– 413.

Williams, M., Davids, K., Burwitz, L., Williams, J. (1993). Cognitive knowledge and soccer performance. *Perceptual and Motor skills*, *76*(2), 579-593.