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Visuomotor reaction time in combat sports

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Abstract

Aim. The purpose of the study is to look into the visuomotor reaction time (simple and complex reaction time) of combat sports athletes.

Material and method. Sixty-eight participants (M_{age} = 21.85) took part in the research. For assessing simple reaction time and choice reaction time two computerized tests were used (TRS and RCMV, respectively), calibrated on the Romanian population by RQ Plus company.

Results. Analysis of variances and Tukey post-hoc test for equal variances were performed to verify the differences in terms of choice and simple reaction time, according to martial arts athletes' sports level. Also, gender-related differences were examined (considering the visuomotor reaction time), using the Goodman and Kruskal tau association test. Data analysis showed that athletes with superior results in competitions registered a faster choice reaction time (even if the difference was not statistically significant). Considering simple reaction time values, the difference between combat sports athletes (according to sports performances) was almost nonexistent. Also, male athletes obtained better values for simple reaction time and slightly better results for choice reaction time than female athletes.

Conclusions. Combat sports athletes having international performances registered better values for choice reaction time, compared to athletes having national, respectively regional/local results. A significant link was found between athletes' gender and martial arts athletes' results for simple reaction time, with male athletes obtaining better scores.

***Key words**: simple reaction time; choice reaction time; combat sports; sports performance.*

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Introduction

In performance sport there are many time-limited scenarios, fast reactions (for the appropriate action) being necessary when new stimuli appear in the athletes' visual field (Sanders, 1998). Reaction time is the time from the occurrence of a signal-stimulus to the initiation of movement of the relevant segment of the body (Schmidt & Wrisberg, 2008). Also, reaction time (RT) is seen as the interval between the appearance of a stimulus (visual, auditory, tactile) and a specific movement, including kinetic and cognitive functions (Raichur, 2013). The participant needs to decode/identify the stimulus and to take the right decision, making the appropriate movement (Senel & Eroglu, 2006). Visuomotor reaction time (VMRT) refers to a person's motor reactions to visual stimuli.

Reaction times (RTs) were first studied in the 19th century by Donders (the Dutch physiologist was talking about the speed of the mental processes - see Lachman et al., 2015), and Francis Galton (Johnson et al., 1985). In its simplest form - simple reaction time (SR), visual RT can be defined as “the time taken to respond (typically via a button press) to the sudden appearance or change of a visual stimulus” (Barrett et al., 2020). Reaction time is measured in ms (milliseconds) or sec (seconds) - for example, 170 ms = 0.17 sec. Through training RT values can decrease (meaning superior results) (Chandra et al., 2010); see, also, Makronasios et al. (2023) study where they reported a 9.2% reduction in RT (a light-sensor system was used) after neuromuscular electrical stimulation. Beyond a certain limit the improvement in performance (RT) stops and a plateau is reached (Aniței, 2007). In the case of simple reaction time (SR) there is one stimulus and one response. With respect to the choice reaction time/ complex reaction time (CR) there are several stimuli and each stimulus has a specific response (e.g., pressing the right buttons or pedals, depending on the signal-stimuli), while recognition reaction time/ discrimination reaction time supposes the participant to respond to the right stimulus and to ignore other stimuli in the environment (Luce, 1986). In the current research the focus was to measure choice RT and simple RT. Choice RT implies the presence of more complex mental processes (compared to simple RT), more exactly, the presence of stimuli identification stage and response selection stage (Waldziński, 2023; Schmidt & Lee, 2005; Predoiu et al., 2016). Therefore, CR is slower by comparison with SR (Folstein et al., 2008).

RTs were used as measures of cognitive functioning (Der & Deary, 2006). Researchers, after a review of fifty years of studies found significant associations between reaction time latencies of processing speed and fluid intelligence (Sheppard & Vernon, 2008). Regarding the aging patterns of SR and CR, it seems that choice RT “slows and becomes more variable throughout adulthood, whereas simple RT barely changes until people are approximately 50 years old” (Der & Deary, 2006). Is important to mention that age-related increases in simple reaction time latencies “are due primarily to slowed motor output” (Woods et al., 2015), and that age-related deterioration in RT was the same for males and females (Jevas & Yan, 2001).

Regarding the link between faster reaction time and sporting performance research is contentious. Some studies reported significant associations between the two variables, more specifically that visual reaction times are faster in elite than in sub-elite athletes (Kalberer et al., 2017) or compared to non-athletes (Helm et al., 2016; Mahesh et al., 2013). Moreover, faster reaction times were observed in athletes having better performances on the field (in baseball, see Classe et al., 1997; Burris et al., 2018). On the other hand, there are studies asserting an inconclusive correlation between visual RT and sporting excellence (Martinez de Quel & Bennett, 2014; Baker et al., 2002; McLeod, 1987).

In martial arts (taekwondo and judo) it was found that athletes registered better simple RT (but not significantly better choice RT) compared to non-athletes (Atan & Akyol, 2014). Also, it seems that most muscles examined have shorter pre-motor times in elite taekwondo athletes than in novices (pre-motor time being the period from the presentation of the stimulus to the onset of muscle activation, when electromyography is used, see Ervilha et al., 2020). But Sadowski et al. (2012) highlighted that simple RT cannot be a predictive dimension of sports success in taekwondo. When simple reaction time was investigated in elite senior karate do practitioners, the results were slightly above average (Macovei et al., 2013). Expert karate athletes obtained better results for simple RT (Fontani et al., 2006) and choice RT (Williams & Elliott, 1999), compared to novices. In fencing, more experienced athletes obtained lower RT (better results) compared to beginners (Milic et al., 2020), the same as in karate kumite (Mudric et al., 2015). However, there are studies emphasizing no significant differences between the two groups of martial artists: beginners and experienced (Gutierrez-Davila et al., 2013; Balkó et al., 2016; Williams & Walmsley, 2000). Considering the differences between combat sports (Greco-Roman wrestling, freestyle wrestling and taekwondo) in simple RT and choice RT, no significant differences were highlighted (Sadowski et al., 2024).

The current study

The purpose of the research is to investigate visuomotor reaction time in combat sports athletes.

Hypotheses

H1: Investigation of visuomotor reaction time (simple and choice reaction time) reveals significant differences between martial arts athletes according to sports performances.

H2: There are significant associations between combat sport athletes' gender and athletes' results for VMRT.

Materials and method

Participants

Sixty-eight senior combat sport athletes took part in the current research, 48 male athletes and 20 female athletes: M_{age} = 21.85, *SD* = 3.29. Inclusion criteria: minimum 18 years old and maximum 30 years old (to be a relatively homogeneous group in age), and minimum two years of competitive experience: $M_{competitive\ experience}$ = 5.48, *SD* = 3.66 (in the entire sample). Athletes are affiliated to different sports clubs, recognized by national federations.

According to sport discipline, athletes practice karate (22 athletes - 14 male athletes and 8 female athletes), boxing (16 athletes - 14 M and 2 F), fencing (16 athletes - 9 M and 7 F) and taekwondo (14 athletes - 11 M and 3 F). 33.8% of athletes have international sport results (top ranks at World and/or European level, of which 6 female athletes), 29.4% of athletes registered national performances (top ranks at national level competitions, of which 7 female athletes), while 36.7% of athletes have regional/local results (of which 7 female athletes).

The snowball and, also, the convenience sampling technique was used to find athletes that meet the inclusion criteria above. *Measures*

For assessing simple reaction time, the TRS test was used (Figure 1), as in previous studies (Grigore et al., 2015; Macovei et al., 2013). The test supposes the existence of 50 reaction trials and the arithmetic mean (in terms of simple RT) is automatically generated. The signal stimulus is represented by a red circle that appears randomly in the center of the screen. Athletes press as fast as they can on the button of a lever, when the signal stimulus appears.

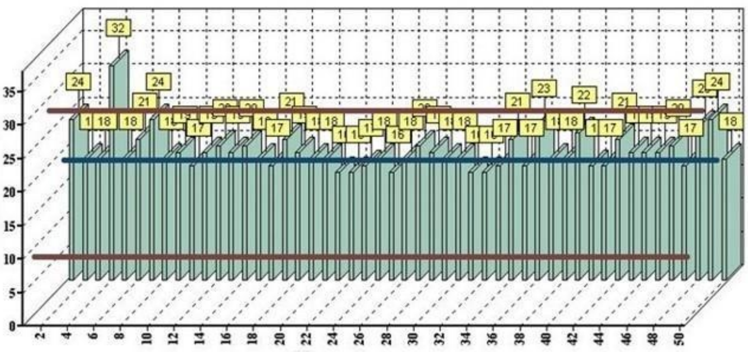

Figure 1. *Output for the TRS test – simple reaction time for each of the 50 trials is presented*

To assess choice/complex reaction time, the RCMV test was used, as in previous studies (Cojocaru et al., 2015; Grigore et al., 2011; Dumitru et al., 2024). The arithmetic mean of choice RT is automatically generated as a result of 66 sequences/ reaction trials. "At variable time intervals and in a randomized order, square-shaped centrallyleft/-right, upward/downward positioned relevant stimuli" (Predoiu, 2015) appear on the computer screen (see Figure 2 to observe the signal-stimuli/red squares on the computer screen).

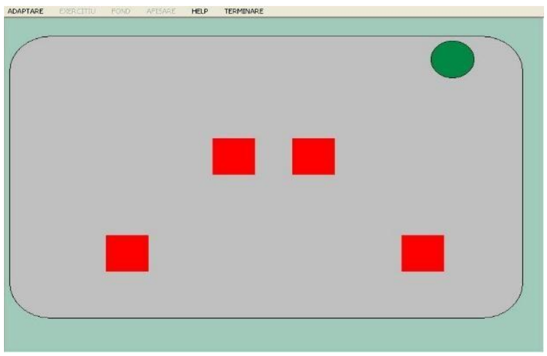

Figure 2. *Choice RT – RCMV test*

Athletes hold a lever in each hand, while feet are placed on pedals. The participant "must respond through a motor reaction of his upper limbs (button pressing) and lower limbs (pedal pushing) […] depending on the number and position of the displayed squares" (Teodorescu et al., 2011). Two or three red squares are visible on the screen in the same time. The computerized test assumes the existence of 6 possible stimuli which require six different motor movements/ actions (6-Choice RT). The mean of the choice reaction time is automatically generated with respect to the speed at which athletes press the correct combination of pedals and/ or buttons.

Procedure

The TRS and RCMV tests were applied (in front of the experimenter) in the period 2023-2024, in Romania. Between 2 and 6 athletes were tested at the same time, between 10 a.m. and 5 p.m. Knowing that Peters and Ivanoff (1999) found that right-handed people were faster with their right hand (as expected), but left-handed people had a good RT with both hands, we took the decision, in the current study, that the dominant hand will be used. Combat sport athletes were in a resting state (without warming up beforehand or exercising to increase heart rate).

With respect to the link between athletes' gender (regardless of sporting results) and athletes' scores for VMRT, the values for simple RT and choice RT have been coded as follows:

- Simple reaction time: 1 = less than 0.17 sec (n = 28), 2 = between 0.17 - 0.19 sec (n = 29) and 3 = over 0.19 sec (n = 11);
- Choice reaction time: 1 = less than 0.80 sec (n = 20); 2 = between 0.80 - 1 sec (n = 23) and 3 = over 1 sec (n = 25).

The rationale behind the choice of 0.19 seconds as a cut-off threshold for simple RT was the literature review on reaction time of Kosinski (2013) arguing that "for about 120 years, the accepted figures for mean simple reaction times for college-age individuals have been about 190 ms (0.19 sec)" in the case of visual stimuli. However, in the current study combat sports athletes were investigated, being known that athletes have a faster RT than non-athletes (Atan & Akyol, 2014).

Ethics

The present study was approved by the local ethics committee of the National University of Physical Education and Sport, Bucharest, authorization number assigned is 920/SG. Anonymity of the participants was ensured, data were treated confidentially, and written informed consent was obtained.

Results

Using box-plots outliers were checked, to avoid the situation where combat sport athletes performed too poorly due to lack of commitment or fatigue (no outliers were found).

The results at descriptive level for visuomotor reaction time are presented in Table I.

Table I. Visuomotor reaction time – descriptive statistics

	Sports performance	CR	SR
N	INT	23	23
	NAT	20	20
	R/L	25	25
Mean	INT	0.854	0.179
	NAT	0.885	0.176
	R/L	0.960	0.170
SD	INT	0.175	0.0212
	NAT	0.189	0.0225
	R/L	0.122	0.0293
Skewness	INT	0.408	1.32
	NAT	-0.0707	1.38
	R/L	0.0317	1.05
Kurtosis	INT	-0.466	1.94
	NAT	-0.764	1.46
	R/L	-0.265	0.689

Note. CR: Choice reaction time; SR: Simple reaction time; INT: International sports performances; NAT: National results; R/L: Regional/Local sports results.

A better CR can be observed for athletes having international sports performances (M_{CR} = 0.854, SD = 0.175), compared to martial arts athletes having national (M_{CR} = 0.885, SD = 0.189), respectively regional/local sports results (M_{CR} = 0.960, SD = 0.122). In terms of SR the differences between combat sports athletes, according to sports performances are almost inexistent.

Table II and Table III emphasize the results of analysis of variances (Fisher's test and Tukey post-hoc test were reported) considering choice RT and simple RT.

Table II. Analysis of variances (ANOVA) - Fisher test results

	F	df1	df2	p	Levene's F/p*
Choice reaction time	2.717	2	65	0.074	2.55/ 0.086
Simple reaction time	0.774	2	65	0.465	1.46/ 0.240

Note. * p > 0.05 in the case of the Levene test, therefore the Fischer test results were reported (the homogeneity condition being met)

Table III. Analysis of variances – Tukey post-hoc test for equal variances

		INT	NAT	R/L
Choice reaction time				
INT	Mean difference	—	-0.0308	-0.1060
	p-value	—	0.810	0.069
NAT	Mean difference		—	-0.0752
	p-value		—	0.277
Simple reaction time				
INT	Mean difference	—	0.0025	0.0086
	p-value	—	0.941	0.453
NAT	Mean difference		—	0.0061
	p-value		—	0.690

Note. INT: International sports performances; NAT: National results; R/L: Regional/Local sports results.

Even if the differences are not statistically significant (p > 0.05), it is worth mentioning that athletes with superior sporting performances registered better values – lower choice RT (a faster information processing, identifying signal-stimuli and selecting appropriate motor responses more quickly), compared to athletes without outstanding sports results (INT < NAT < R/L for CR, see Table 1).

In the next step, the existing correlation between athletes' gender (regardless of sporting performance) and athletes' results for VMRT was verified, using Goodman and Kruskal tau association test. Table IV includes only the significant correlation found.

Table IV. Directional Measures - Goodman and Kruskal tau association (SR)

		Value/ Asymp. Std. Error	p
Goodman and Kruskal tau	Gender	0.174/ 0.098	0.003
	Simple RT - Dependent variable	0.057/ 0.038	0.022

Crosstabulation Gender and Simple reaction time

	Simple reaction time			
	less than 0.17	0.17-0.19	over 0.19	Total
Male martial arts athletes	22 (45.8%)	23 (47.9%)	3 (6.25%)	48

Female martial arts athletes	6 (30%)	6 (30%)	8 (40%)	20
Total	28	29	11	68

Results in Table IV emphasize that out of the 48 male combat sport athletes: 22 athletes (45.8%) registered less than 0.17 sec, 23 athletes (47.9%) obtained between 0.17-0.19 sec, while 3 athletes (6.25%) over 0.19 sec. In the case of female athletes, out of the 20 athletes: 6 athletes (30%) registered less than 0.17 sec, 6 athletes (30%) obtained between 0.17-0.19 sec, while 8 athletes (40%) over 0.19 sec. A significant association (p = 0.022) can be found between athletes' gender and combat sport athletes' results for simple RT, with male athletes obtaining better scores ($M_{\text{male athletes SR}}$ = 0.170, *SD* = 0.018; $M_{\text{female athletes SR}}$ = 0.186, *SD* = 0.033). Cramer's V (effect size) value is 0.418, emphasizing a moderate to strong link between variables. Data in Table V reveals, also, slightly better results for CR in male athletes (even if no significant gender-related associations were found).

Table V. CR and SR according to gender (descriptive statistics)

	Gender	CR	SR
N	1 male (n = 48)		
	2 female (n = 20)		
Mean	1 male	0.894	0.170
	2 female	0.924	0.186
SE	1 male	0.023	0.002
	2 female	0.040	0.007
Median	1 male	0.897	0.172
	2 female	0.988	0.180
SD	1 male	0.160	0.018
	2 female	0.182	0.033

Note. CR: Choice reaction time; SR: Simple reaction time.

Discussions

Specialists in the field of sport are constantly looking for ways to develop athletes and improve performances. The aim of the current study was to examine the visuomotor reaction time (simple reaction time and complex reaction time) of combat sports athletes. Literature highlights the need, in sports, to assess the ability to quickly respond to stimuli using the choice reaction time (Milic et al., 2020). Research has indicated that a slower visuomotor reaction time is linked to a higher risk of injury (Brinkman et al., 2020). Also, specialized literature emphasizes the importance of rapid reaction and discrimination between stimuli in sport, generally (Cashmore, 2008), and in combat sports (Cojocariu et al., 2019; Riyadi et al., 2020).

In a first phase we found no significant differences between athletes, according to sports performances, for choice RT and simple RT. However, choice RT was better in martial artists having superior results in competition (INT < NAT < R/L). This is in line with Cojocariu and Abalasei (2014) findings - authors did not found significant differences for both visual CR and SR between athletes placed on the top national rankings (judo) and non-athletes, but experienced athletes obtained slightly better reaction times. Also, even if no statistically significant differences were observed between medallists and athletes who did not win medals (in taekwondo), medallists registered shorter/better RT (Sadowski et al., 2012). It is worth noting that in a sporting display a very small difference in the athletes' reaction time may distinguish between the winner and loser (Śliż et al., 2023). We mention, also, Hülsdünker et al. (2018) findings, researchers highlighting the exceptional perceptual-motor abilities of experienced athletes in the visual system.

With respect to simple RT, in the present study, the differences are scarce between the investigated combat sport athletes (when the sporting performance criterion has been used). Coșkun et al. (2014) also failed to underline significant differences in reaction time between international and national karate kumite competitors. The findings of the current research, generally, support the inconclusive relation between visual RT and sporting success (see, also, Martinez de Quel & Bennett, 2014; Helsen & Starkes, 1999).

The existing correlation between athletes' gender and athletes' results for visuomotor RT was, also, examined. A significant relation was found only for simple reaction time, with male athletes obtaining a faster SR, on average by 0.016 seconds than female athletes. Studies have found that in almost every age group, males have better RT than females (Der & Deary, 2006; Davis et al., 2000; Dane & Erzurumluoglu, 2003). Considering choice RT, no significant gender-related correlation was found. However, slightly better results for choice reaction time were observed in favor of male combat sport athletes. Dane and Yilmaz (1999) underlined a male advantage in the visuomotor activities (normal human subjects were examined). Adam et al. (1998) discussed, also, about male advantage - i.e. a shorter choice RT (overall). On the other hand, there are studies reporting contradictory findings considering choice reaction time, in a visual RT task (Lahtela et al., 1985), in tasks supposing finger RT (Landauer, 1981) or finger dexterity (Lachnit & Pieper, 1990). Not least, in combat sports, elite female athletes practicing taekwondo registered faster reaction time than males during a striking kick (in an ecological context) (Ervilha et al., 2014). The findings of the current study support athletes, coaches and sport psychologists for a better understanding of the information processing speed in combat sports.

Limitations and future directions

The sample of combat sport athletes is not very large, new studies being necessary, and, also, each sport branch could be separately examined (e.g., fencing, taking into account the weapon used, or boxing, taking into consideration the weight category). Futures studies could use music as a performance-enhancing strategy, before the computerized testing, knowing that listening research-selected music and self-selected music can improve visual choice RT in elite taekwondo athletes (Greco et al., 2024). Also, Welford (1980) found that the best reaction time was registered under an average level of activation of the organism. Fatigue influence RTs (see Kosinski, 2013; Sant'Ana et al., 2017), and new studies may consider this aspect as well (e.g. testing elite and sub-elite athletes' reactions after an intense training). Because choice reaction time increases with the number of stimulusresponses alternatives (Schmidt & Lee, 2005) – in agreement with the Hick's law (Hick, 1952), further studies could examine choice RT supposing a different number of correct reactions/ movements, e.g., 4-Choice RT, 2Choice RT (in the present study there were six possible stimuli which were associated with six different responses/correct movements, therefore, a 6-Choice RT). Not least, in the current research almost 91% of martial artists were right-handers (future studies may address only left-handers or only right-handers).

Conclusion

In summary, we assert that a better choice RT (even if not statistically significant) was observed in combat sports athletes having international performances, compared to athletes having national, respectively regional/local results. With respect to simple RT the differences between combat sports athletes (according to sports performances) are almost nonexistent. Also, a significant link was found between combat sports athletes' gender and athletes' results for simple RT, with male athletes obtaining better scores. Even if no gender-related correlation was underlined for choice reaction time, slightly better results were observed in favor of male martial arts athletes.

Declaration of conflicting interests

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

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