SPEED AND DISTANCE ESTIMATION IN COMBAT SPORTS

Radu PREDOIU[1], Alexandra PREDOIU[2*], Rareș STĂNESCU[2], Faten HAMDI[3], Gabriela DINȚICĂ[2], Costel OZARCHEVICI[4], Lavinia PAVEL[5], Germina COSMA[6]

1 University of Craiova, Doctoral School of Social Sciences and Humanities, Craiova, Romania

2 National University of Physical Education and Sports, Faculty of Physical Education and Sport, Bucharest, Romania

3 University of Jendouba, High Institute of Sport and Psysical Education, El Kef, Tunisia

4 "Alexandru Ioan Cuza" Police Academy, Faculty of Police, Bucharest, Romania

5 "Sportul Studențesc" Sports Club, Bucharest, Romania

6 University of Craiova, Faculty of Physical Education and Sport, Craiova, Romania

**Corresponding author: alexandra.predoiu@yahoo.com*

https://doi.org/10.52846/jskm/44.2024.1.1

Abstract. The ability to position oneself taking into consideration the movements of people or objects is essential in the sporting context. The purpose of the study was to examine the level of speed and distance estimation in combat sports, according to athletes' performances and sports discipline practiced. Sixty-six combat sport athletes took part in the present research, 45 males and 21 females, aged 18-26 years ($M_{age} = 21.22$). The computerized test ADV (Distance and Speed Estimation Test) was applied. Estimation was assessed based on athletes' capacity to process the speed of moving objects (red balls moving in circles) and the distance to be covered. The Kruskal-Wallis (H) test was used to check the differences between combat sport disciplines in terms of speed and distance estimation and, also, to verify if the results for speed and distance estimation are significantly related to athletes' sports performances. The Dwass-Steel-Critchlow-Fligner (DSCF) statistical procedure was used to verify groups two by two. Significant differences were emphasized ($p = 0.036$) between athletes with international performances ($M_{\text{speed and distance estimation}} = 4.61$) and combat sport athletes having regional/local sports results ($M_{\text{speed and distance estimation}} = 4.05$). Martial artists having superior results in competitions demonstrated a better ability to estimate speeds and distances in a two-dimensional environment.

Keywords: *speed estimation, motion perception, depth perception, exocentric distance, combat sports.*

Introduction

Combat sports are heuristic sport branches (with creative opponent) and can be examined as striking combat sports (e.g., taekwondo, karate, boxing, fencing) or grappling combat sports (for example, jiu-jitsu and judo), the same as in previous studies (Patenteu et al., 2023; Predoiu et al., 2022; Predoiu et al., 2024). In the case of fencing, it is worth mentioning that it is a combat sport (Bagińska et al., 2022), being in the category called *working with weapons* (see the division of the combat sports - Kalina, 2000). In striking combat sports (SCS), the intermittent and complex nature of fighting in competitions implies the existence of different strikes, which can last even milliseconds (Borysiuk, 2006).

Specialized literature asserted the importance, in sport, of good perceptual abilities, of a high level of distance, space and speed estimation (Çetin et al., 2011). Speed estimation and distance estimation represent "hard skills" (see Fleishman & Reilly, 1992), being necessary for sporting success. In striking combat sports we can discuss about the speed of complex reactions to stimuli, the speed to perform a series of strikes/combinations, about decision-making speed, the frequency of strikes, or about the speed of movement from a specific position (Gumienna et al., 2024). It was found that the duration of athletes' kick is approximately half a second (taekwondo athletes were investigated, see Wąsik & Shan, 2015), while in karate the attack velocity for a punch is approximately 2.7-3.0 milliseconds (Chiu & Shiang, 1999). Therefore, during training and competitions combat sport athletes should pay special attention to developing speed and distance estimation.

Many daily activities depend on the capacity to estimate speed, distance, time, or to recognize objects in due time, these estimations being essential for the survival of organisms in dynamic environments, for our efficient interaction with the surrounding reality. Producing estimates is a complex task that entails various cognitive abilities, including the ability to use prior experience in flexible ways and to monitor the accuracy of responses (Hoffman & MacPherson, 2022). It seems that males (generally) have better results in visual estimation tasks compared to females, while “estimates of speed and movement based on visual information were less affected by age than estimates of duration and sound based on auditory information” (Tapia et al., 2022). Estimation difficulties are related to individuals with frontal lobe injury (Shallice & Evans, 1978), traumatic brain injury (Silverberg et al., 2007), schizophrenia (Khodarahimi & Rasti, 2011) in adults with Alzheimer’s disease (Levinoff et al., 2006), major depressive disorder (Barabassy et al., 2010), or Parkinson’s disease (D’Aniello et al., 2015). It is worth mentioning, however, Scarpina et al. findings (2017) which emphasized no significant difference between participants with Parkinson’s disease and controls.

The appreciation of the speed of an object in sport (and beyond) is inextricably linked to the perception of motion. Movement always implies a certain speed and space (e.g. a person is moving and estimates speed in different spaces - on the field in sport, on the street, corridor, highway, etc.). However, an object will be perceived in motion only if the speed at which it is moving is not too high (think, for example, of identifying the tips of a propeller) or too low (we cannot see grass growing, or one can think of the way a clock works – we can discern that it has changed its position/indicates a different time, only after a certain time). Thus, sense organs react to a certain speed/rate of change, fixed in the course of phylogeny (see Predoiu, 2010).

Like motion, speed is also relative and is dependent on the type of moving object. For example, if a racing car, a horse and a cart are moving at the same speed, we will judge that the racing car is moving relatively slowly, while the cart has considerable speed (Grütter, 2020). A higher speed significantly reduces the visual/perceptual field that one can monitor, losing details of the surrounding environment (this is why our perception is different when visiting a place on foot compared to when we pass through the area traveling in a car). Usually, the feeling that the speed is too high in competition (the opponent hits too fast, or the ball comes too fast) is associated with loss of control and decreased performance (the athlete feels that he/she does not have enough time to defend or react, see Predoiu, 2018). To better estimate speed, temporal and spatial cues are of particular importance (perception of object motion is based on spatial and temporal perception). The rhythm and sequence of movements (as temporal properties of movement), when we quasi-simultaneously perceive successive aspects of movements and perceive duration (Zlate, 1999), together with the spatial properties of movements such as direction and shape (e.g., bottom up/top down, forward or backward, from right to left/left to right, straight, circular, curved, see Predoiu, 2012) enhance performance in speed and distance estimation tasks. But we don't seem to perceive motion and speed the same in all directions. Horizontal movements are easier to perceive than vertical ones, left-to-right motions are easier to perceive (compared to right-to-left movements, which require more effort from the person). Last but not least, a top-down movement is more easily perceived (due to gravity), as opposed to an object moving the other way around – bottom-up (Grütter, 2020).

From the first weeks of life, the child keeps its head out of the way of moving objects, dangerous or not (Miclea, 1999). Children (6 years old) have more difficulties in anticipating movements and the appearance of significant stimuli (after they disappeared from the screen shortly after initial movement), compared to adolescents (Dorfman, 1977). Benguigui et al. (2004) showed, also, that children obtained poorer performance in estimating arrival-time (the anticipation of a target stimulus that disappeared from view shortly after initial movement) than adults. Over time, specialists have investigated (in children) when the perceptual invariant of speed is acquired. Under the age of 8, if an object precedes another object in time or space, it is perceived as being faster (speed intuition is ordinal, see Aniței, 2007). At a later stage of cognitive development, a child will understand that a reduction in the distance between two objects (moving on the same trajectory) means that the second object (the one behind) starts to move faster, while an increase in the distance between objects means that the first object (the one ahead) starts to move even faster. This process, which involves the perception of the existing distance between objects, and the order of objects during movement, has been termed by Piaget as hyperordinal (see, for example, Predoiu, 2012). Not least, Bruffaerts et al. (2019) underlined the importance, for the processing of perceptual information of visual objects, of the combination between semantic data (useful for a better representation of the object), and explicit models of vision (in young participants, data are represented within the first 150 milliseconds of object presentation - Clarke et al., 2015).

Speed and motion can be perceived also, in situations when they are not actually real. There are several kinds of motion, of which: real (when an object is moving from one point to another) and apparent, when an object is motionless and yet appears to be moving (see Predoiu, 2010). If we think of a movie, it consists of static images that follow each other rapidly, usually 24 images per second (Grütter, 2020). Thus, we see the whole as motion, and not the static images independently. The nervous system creates this sensation of motion by integrating different temporary excitations, each of which actually registers only a static change.

Visual speed and its estimation also depends on the size of the object. Small objects appear to move faster than large objects, while a smaller visual field influences how we perceive the acceleration (Aniței, 2007). In order to preserve the visual impression of an object's motion it is recommended that the size of the moving objects varies directly proportional to the size of the frame/space in which the objects are moving (otherwise, if we only increase the frame/space, the speed of the objects appears to decrease).

Motion perception and, thus, speed estimation is based on the fact that the moving object (e.g. a ball) is tracked by the eye, the projection of the object remaining on the retina. The literature also discusses kinesthetic perception, operational only when the observer is in motion (Grütter, 2020). Speed estimation and motion, as well as surface detection and contour extraction, or segregation of the figure from the background (for example, we automatically perceive a basketball hoop in a sports hall, while the walls of the sports hall remain in the background) represent unconscious processing of information, performed automatically (without conscious and deliberate effort) by *cognitive modules* located at the unconscious level and involved in stimuli processing (Miclea, 1999).

Although the human being has no special analyzer for distance and depth, and although the image of the object is two-dimensional on the retina, we can also perceive the third dimension. In common parlance we can talk about overestimation or underestimation of a distance (e.g. to a certain object). The size of the retinal image, chromatic features, presence of details, presence/absence of landmarks play an essential role in the correct perception of the distance to an object (Rosca, cited by Predoiu, 2012). Thus, size and distance cannot be properly estimated if distance-related cues/ landmarks to an object are missing or reduced. The perception of depth and distance is based on the existing links, from the first months of a child's life, between different analyzers. In Joe Campos' Laboratory (University of California - Berkeley, USA) researchers highlighted the important role of peripheral vision and children's experience gained while moving (crawling infants) on depth perception. Therefore, after some experience in moving, and after being more attentive to peripheral vision, children (who haven't yet learned to walk, having only a few months old) refused to cross a visual cliff (Figure 1), because they know what depth and the perceived distance imply (U.S. National Science Foundation, 2015).

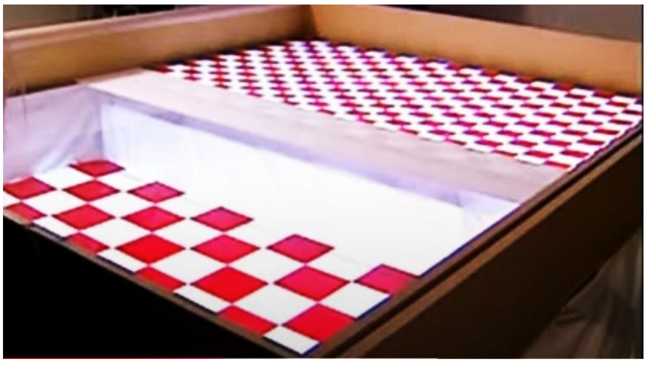

Figure 1. Visual cliff – depth and distance perception

Depth perception is the capacity to perceive distance to objects in external environment. „Distance perception and depth perception are often considered synonymous. However, they can also be subtly distinguished such that depth perception specifically refers to perception of exocentric distance" (the distance between two external objects), while egocentric distance refers to the distance between a person and an external object (Yamamoto, 2017).

In the case of a drawing and the perception of depth in a drawing, the bright parts come to identify protrusions and the shaded parts to be interpreted as indentations (although the surface is flat). As indicators of distance, one can notice changes in the size of objects on the retina, as well as changes in the kinesthetic impulses of the eyeball muscles when we shift our gaze from a near to a distant object and vice versa. In addition to these distance signals/cues literature underlines: interposition (the position of one object relative to the others), motion and aerial perspective (see Predoiu, 2010; Predoiu, 2012). But human beings not only have visual distance perception. Distance can be experienced through multiple senses, such as haptics (Lederman & Klatzky 2009) or audition (Kolarik et al. 2016).

In sports, it was found that divers underestimated their depth, while when diving below 10.7 meters they began to overestimate the depth (Ross & Franklin, 1976). Also, it seems that novice divers "made deeper depth estimates than the experienced group because they were more anxious" (Gassman, 1985). In fencing, depth sensors were used, "to measure the distance to the object in the observed scene" (Malawski, 2020), the investigation of distances in sport and human motion being of interest to all specialists involved in the sports performance field.

Purpose

The aim of the study is to examine the level of speed and distance estimation in combat sports, according to athletes' performances and sports discipline practiced.

Hypotheses

H1: There are significant differences between athletes practicing different combat sport disciplines in terms of speed and distance estimation.

H2: The investigation of speed and distance estimation reveals significant differences between combat sport athletes according to their sport results.

Materials and method

Participants

Sixty-six Romanian combat sport athletes took part in the present research, 45 males and 21 females, aged 18-26 years (M_{age} = 21.22, *SD* = 2.90). Minimum two years of competitive experience and having minimum 18 years old represented inclusion criteria for this study. Athletes have between 2-12 years of competitive experience ($M_{in\ the\ entire\ sample}$ = 5.65, *SD* = 2.53), being affiliated to sports clubs recognized by national sports federations.

Combat sport practitioners are distributed as follows:

- boxing: 17 athletes (25.75%) - 15 males (M) and 2 females (F), 2 obtained international performances (top ranks at World and/or European championships), 8 registered national sports results (top ranks at national level competitions), and 7 athletes obtained regional/local results;
- fencing: 16 (24.25%) - 7 M and 9 F, 6 obtained international performances (top ranks at World and/or European championships), 5 registered national sports results, while 5 athletes obtained regional/local results;
- karate: 20 athletes (30.3%) - 14 M and 6 F, 8 obtained international performances, 5 registered national results (top ranks at national level competitions), and 5 athletes obtained results at regional/local level;
- taekwondo: 13 (19.7%) - 9 M and 4 F, 2 having international performances, 6 athletes with national sports results, and 5 having regional/local performances.

Sports disciplines are investigated, at group level, as *striking combat sports*, as in previous studies (Predoiu et al., 2022; Patenteu et al., 2024; Predoiu et al., 2024).

Measures and Procedure

The computerized test ADV (for assessing speed and distance estimation) was applied between 2023-2024. The test is calibrated on the Romanian population being developed by RQ Plus (a Romanian company). The ADV test was applied between 9 a.m. and 4 p.m. (on different days of the week). The athletes' eyes were about 50 centimeters away from the computer screen.

ADV computerized test consists of a blue screen on which are placed six white concentric circles, and in each circle, a red colored ball rotates clockwise (3 of the red balls), but, also, counter clockwise (the other 3 red balls). The stimuli (represented by the 6 red balls) move at different speeds, each ball in its own space/circle (inside the six concentric circles). When the red balls on space/circle 2, 4 and 6 are lined up on the left side of the screen (exactly in the middle of the screen), the participant must press the left button on the lever. When the significant stimuli (the red balls which move in the space/circle 2, 4 and 6) are aligned on the right side of the screen (exactly in the middle of the screen) the participant should press the right button of the lever. Estimation was assessed based on athletes' capacity to process the speed of moving objects (red balls moving in circles) and the distance to be covered.

At some point, the six white concentric circles disappear from the screen, and the participant has to estimate speed and distance under these conditions (the participant should not lose sight of significant stimuli). Thus, the six red balls move (in circle) at different speeds on the blue screen, and the participant has to appreciate when the balls which move in the space/circle 2, 4 and 6 (but the white concentric circles are no longer visible at this point of the test) line up exactly in the middle of the screen (on the left part of the screen, respectively on the right part of the screen), and press the corresponding button on the lever (left or right). Estimation processes allow athletes to predict the red balls' future location based on their speed, distance, and the corresponding time.

The ADV test automatically generates raw scores for speed and distance estimation (SDE), divided into 5 classes reflecting athletes' level of performance. More exactly, Class 5 means very good performances, Class 4 good results, Class 3 means average performances, Class 2 weak results, while Class 1 emphasizes very weak results.

Results

First, athletes' results for speed and distance estimation are presented, at descriptive level (Table 1).

Table 1. Descriptive statistics – SDE coefficient and performance level (classes)

Item	combat sports	SDE	Performance level
Number of athletes (N)	1 boxing	17	17
	2 fencing	16	16
	3 karate	20	20
	4 taekwondo	13	13
Mean	1 boxing	553	4.29 (class)
	2 fencing	607	4.56 (class)
	3 karate	588	4.45 (class)
	4 taekwondo	469	4.00 (class)
Std. error mean	1 boxing	52.6	0.223
	2 fencing	45.2	0.157
	3 karate	41.7	0.153
	4 taekwondo	62.6	0.300
Standard deviation	1 boxing	217	0.920
	2 fencing	181	0.629
	3 karate	187	0.686
	4 taekwondo	226	1.08
Range	1 boxing	722	3
	2 fencing	527	2
	3 karate	527	2
	4 taekwondo	710	3

Note. Class 5: very good performances; Class 4: good results; Class 3: average performances; Class 2: weak results; Class 1: very weak results; SDE: speed and distance estimation (automatically generated by the computerized test).

Examining Table 1, good to very good results for speed and distance estimation can be observed, at group level, in fencing (M = 4.56) and karate (M = 4.45), and good results (generally) for boxing (M = 4.29) and taekwondo (M = 4).

To check the research hypotheses, the Kruskal-Wallis test was used.

Table 2. Kruskal-Wallis (H) test – differences between sports disciplines in terms of speed and distance estimation coefficient

Item	χ^2	df	p
Speed and distance estimation coefficient	3.22	3	0.358

Table 2 emphasizes no significant differences for speed and distance estimation (chi-square = 3.22, p = 0.358) between the investigated combat sport discipline (null hypothesis is accepted).

We further verified if the results for speed and distance estimation are significantly related to martial arts athletes' sports performances (n = 18 – combat sport athletes having international performances, n = 26 – athletes having national sports performances, n = 22 – athletes with regional/local results).

Table 3. Kruskal-Wallis (H) test – SDE coefficient and performance level (classes) according to athletes' sports results

Item	χ^2	df	p	ε^2
Speed and distance estimation coefficient	5.18	2	0.075	0.079
Performance level (classes)	6.75	2	0.034	0.103

Note. Class 5: very good performances; Class 4: good results; Class 3: average performances; Class 2: weak results; Class 1: very weak results; SDE: speed and distance estimation (automatically generated)

Data analysis revealed significant differences (chi-square = 6.75, p = 0.034, see Table 3) for the classes in which the athletes are automatically classified based on their raw scores at the speed and distance estimation test (in other words, based on the speed and distance estimation coefficient). The effect size index (epsilon^2) highlights a moderate difference between groups (Rea & Parker, 2014).

The Dwass-Steel-Critchlow-Fligner (DSCF) procedure was used to verify groups two by two (Table 4 and Table 5).

Table 4. DSCF test – differences between athletes according to sports results (SDE coefficient)

Speed and distance estimation coefficient		W	p
1 International performances	2 National sports performances	-1.20	0.672
1 International performances	3 Regional/Local results	-3.12	0.070
2 National sports performances	3 Regional/Local results	-2.16	0.277

Table 5. DSCF test – differences between athletes according to sports results (performance level/classes)

Performance level/classes (ADV test)		W	p
1 International performances	2 National sports performances	-1.39	0.588
1 International performances	3 Regional/Local results	-3.50	0.036
2 National sports performances	3 Regional/Local results	-2.48	0.186

Data in Table 5 underline significant differences for speed and distance estimation (p = 0.036) between combat sports athletes having international performances and athletes who registered regional/local sports results. Table 6 presents the descriptive statistics indicators, the best results for speed and distance estimation being obtained by athletes having international results ($M_{\text{raw score}}$ = 624, SD = 202; $M_{\text{class/level of performance}}$ = 4.61, SD = 0.778).

Table 6. Descriptive statistics – SDE coefficient and performance level (classes) according to athletes' sports performances

Item	Sports performances – combat sports athletes	Speed and distance estimation coefficient	Performance level
Number of athletes (N)	1 International performances	18	18
	2 National sports performances	26	26
	3 Regional. Local results	22	22
Mean	1 International performances	624	4.61 (class)
	2 National sports performances	580	4.42 (class)
	3 Regional. Local results	485	4.05 (class)
Std. error mean	1 International performances	47.6	0.183
	2 National sports performances	40.0	0.159
	3 Regional. Local results	40.0	0.180
Standard deviation	1 International performances	202	0.778
	2 National sports performances	204	0.809
	3 Regional. Local results	187	0.844

Note. Class 5: very good performances; Class 4: good results; Class 3: average performances; Class 2: weak results; Class 1: very weak results. SDE: speed and distance estimation (automatically generated)

Discussion

The ability to position oneself according to other athletes' movements, or according to different objects in the environment is essential in the sports field. Speed and distance estimation tasks have a sensory-perceptual component. Seeing an athlete in motion and predicting its future movement and location involves, also, attention, processing load, judgment, imagery, memory, decision-making, etc. Cognitive estimation represents, thus, a complex process of creating an approximation based on available data, which are, however, incomplete (Fortune & Richards, 2017). As MacPherson et al. (2014) argued, “to produce reasonable cognitive estimates, individuals need to identify and select the appropriate cognitive set […], monitor the appropriateness of their response and repeat the procedure if necessary to produce a better estimate”.

Statistical data processing revealed good to very good results for speed and distance estimation, at group level, for fencing and karate, and (generally) good performances for boxing and taekwondo, the differences between the investigated combat sport disciplines not being statistically significant. These relatively small differences between combat sports could be explained by the fact that in taekwondo (obtained the lowest result), athletes use their feet more in fighting (compared to the other combat disciplines examined), and in the current study athletes had to use their hands to press the right buttons when they needed to judge speeds and distances. Specialized literature emphasized significantly better results for speed and distance estimation (the same ADV test was used) for athletes practicing individual and team sports, compared to non-practitioners; also, athletes from individual sports (karate, taekwondo, tennis and gymnastics) obtained better results when estimating speed and distance, compared to athletes from team sports: football, basketball and handball (Grigore et al., 2013). In the current research young athletes were investigated. In this context, it is worth emphasizing that in middle-aged and mature people, visual processing becomes slower (Onofrj, 2001).

Data analysis showed, also, significant differences for speed and distance estimation between athletes having international performances and combat sport athletes who registered regional/local results. Athletes with superior performance in competition appreciate speeds and distances significantly better. Not least, even if the results are slightly better for athletes with international results, no significant differences were found when compared to athletes having national performances. Other psychomotor skills (coordination, reaction time, etc.) could generate statistically significant differences between the two groups of combat sport athletes, aspects which require further investigation.

Athletes can improve the ability to make estimations. Specialists should use cognitive stimulation exercises which allow athletes to improve brain functions like estimation. Research in the field of neuroplasticity has shown that “the more we use a specific neural circuit, the stronger it gets”, and when the training is “applied to the neural circuits used in estimation, we are able to […] improve our ability to predict and estimate future events and locations” (see CogniFit). The ADV test can be used, also, in training to stimulate athletes' ability to appreciate distances and speeds.

In martial arts (karate, Tai-chi), researchers used sensors for depth estimation (e.g., Kinetic, ToF), the distance between different objects (exocentric distance) and between athletes and external objects (egocentric distance) being explored, for real-time sports analysis, in order to improve execution and sports performance (Zhang et al., 2017), the same as in fencing (Malawski, 2020).

The present study has certain limitations, maybe the most important referring to the relatively reduced number of athletes in each combat sport group. Different findings could be highlighted, in terms of speed and distance estimation, if only male or female athletes would be examined, juniors (not seniors, as in the present research), athletes practicing grappling combat sports (wrestling, jiu-jitsu, judo), or Mixed Martial Arts artists. Future studies may use, also, other computerized assessment tools for speed and distance estimation, for example The Vienna Test System (see ZBA test) or CogniFit, and a three-dimensional environment (using, for example, 3D glasses, virtual and augmented reality).

Conclusions

Good to very good performances for the ability to assess speed and distance accurately were underlined, at group level, in fencing and karate, while good results were observed in boxing and taekwondo practitioners. Significant and moderate differences were found between combat sport athletes with international results and athletes having regional/local sports performances. Martial arts athletes with superior results in competition have a better ability to estimate the speed of moving objects and distances in a two-dimensional environment.

__Authors' Contribution.__ The third, fifth and sixth authors equally contributed to the publication as the first author.

__Funding.__ This study did not receive any external funding.

__Informed Consent Statement.__ The written informed consent for the participants was obtained.

__Conflicts of Interest.__ The authors declare no conflicts of interest.

References

Aniţei, M. (2007). *Psihologie experimentală* [Experimental Psychology]. Credis.

Bagińska, J., Piepiora, P., Piepiora, Z., & Witkowski, K. (2022). The geography of Olympic combat sports - part two: boxing, fencing, modern pentathlon, wrestling. *Archives of Budo, 18*, 327–340.

Barabassy, A., Beinhoff, U., & Riepe, M. W. (2010). Cognitive estimation in aged patients with major depressive disorder. *Psychiatry research, 176*(1), 26-29. https://doi.org/10.1016/j.psychres.2008.06.045

Benguigui, N., Broderick, M., & Ripoll, H. (2004). Age differences in estimating arrival-time. *Neuroscience Letters, 369,* 197–202. DOI: 10.1016/j.neulet.2004.07.051

Borysiuk, Z. (2006). Struktura czasowa procesów informacyjnych w wybranych sportach walki [Temporal structure of information processes in selected combat sports]. *Studia I monografie AWF w Warszawie*, 17–18.

Bruffaerts, R., De Deyne, S., Meersmans, K., Liuzzi, A. G., Storms, G., & Vandenberghe, R. (2019). Redefining the resolution of semantic knowledge in the brain: advances made by the introduction of models of semantics in neuroimaging. *Neuroscience & Biobehavioral Reviews, 103,* 3-13. DOI: 10.1016/j.neubiorev.2019.05.015

Çetin, M. Ç., Taşğın, Ö., & Arslan, F. (2011). The relationship between reaction time and decision-making in elite kickboxing athletes. *World Applied Sciences Journal, 12*(10), 1826-1831.

Chiu, H. T., & Shiang, T. Y. (1999). A new approach to evaluate karate punch techniques. *International Society of Biomechanics Conference Proceedings Archive*, 61-64.

Clarke, A., Devereux, B. J., Randall, B., & Tyler, L. K. (2015). Predicting the time course of individual objects with MEG. *Cerebral cortex, 25*(10), 3602-3612. https://doi.org/10.1093/cercor/bhu203

CogniFit. *Estimation Cognitive Skill – Motor-Perceptive Ability*. https://www.cognifit.com/science/estimation?srsltid=AfmBOorgWIQcCbrYCf1IiDQUZyxhjYDVB8uRUi9SwjI5y0W7FIbCqG31 (*last accessed: 24.11.2024*)

D'Aniello, G. E., Scarpina, F., Albani, G., Castelnuovo, G., & Mauro, A. (2015). Disentangling the relationship between cognitive estimation abilities and executive functions: a study on patients with Parkinson's disease. *Neurological Sciences, 36*, 1425-1429. DOI: 10.1007/s10072-015-2158-5

Dorfman, P. W. (1997). Timing and anticipation: a developmental perspective. *Journal of Motor Behavior, 9*, 67–79. https://doi.org/10.1080/00222895.1977.10735096

Fleishman, E. A., & Reilly, M. E. (1992). *Handbook of human abilities*. Consulting Psychologists Press.

Fortune, D. G., & Richards, H. L. (2017). Assessing cognitive estimation and its effects on community integration in people with acquired brain injury undergoing rehabilitation. *BioMed research international, 2017*(1): 2874819. DOI: 10.1155/2017/2874819

Gassman, N. (1985). A comparison of depth estimation between novice and experienced sport divers. *Journal of sports sciences, 3*(1), 27-31.

Grigore, V., Mitrache, G., & Predoiu, R. (2013). Speed and Distance Estimation – "Hard Skills" in Sports. *Procedia-Social and Behavioral Sciences, 84*, 1114-1118. https://doi.org/10.1016/j.sbspro.2013.06.710

Grütter, J. K. (2020). *Basics of Perception in Architecture*. Springer Fachmedien Wiesbaden.

Gumienna, R., Machowska-Krupa, W., & Kosendiak, J. (2024). Speed of performing complex movement tasks under decision-making conditions as a determinant of the tactical preparation level in kickboxers. *Scientific Reports, 14*(1): 3002. https://doi.org/10.1038/s41598-024-53652-6

Hoffman, P., & MacPherson, S. E. (2022). What determines cognitive estimation ability? Changing contributions of semantic and executive domains as a function of age. *Journal of Neuropsychology, 16*(3), 481-497. https://doi.org/10.1111/jnp.12279

Kalina, R. M. (2000). *Teoria sportów walki* [Theory of combat sports]. COS.

Khodarahimi, S., & Rasti, A. (2011). Cognitive estimation in patients with Alzheimer's disease and schizophrenia. *Journal of Neuroscience and Behavioral Health, 32*, 27-31.

Kolarik, A. J., Moore, B. C. J., Zahorik, P., Cirstea, S., & Pardhan, S. (2016). Auditory distance perception in humans: A review of cues, development, neuronal bases, and effects of sensory loss. *Attention, Perception, & Psychophysics, 78,* 373–395. DOI:10.3758/s13414-015-1015-1.

Lederman, S. J., & Klatzky, R. L. (2009). Haptic perception: A tutorial. *Attention, Perception & Psychophysics, 71*, 1439–1459. DOI:10.3758/APP.71.7.1439.

Levinoff, E. J., Phillips, N. A., Verret, L., Babins, L., Kelner, N., Akerib, V., & Chertkow, H. (2006). Cognitive estimation impairment in Alzheimer disease and mild cognitive impairment. *Neuropsychology, 20*(1): 123. DOI: 10.1037/0894-4105.20.1.123

MacPherson, S. E., Wagner, G. P., Murphy, P., Bozzali, M., Cipolotti, L., & Shallice, T. (2014). Bringing the cognitive estimation task into the 21st century: normative data on two new parallel forms. *PloS one, 9*(3): e92554. DOI: 10.1371/journal.pone.0092554

Malawski, F. (2020). Depth versus inertial sensors in real-time sports analysis: A case study on fencing. *IEEE Sensors Journal, 21*(4), 5133-5142.

Miclea, M. (1999). *Psihologie cognitivă: modele teoretico-experimentale* [Cognitive psychology: theoretical and experimental models]. Polirom.

Onofrj, M., Thomas, A., Iacono, D., D'Andreamatteo, G., & Paci, C. (2001). Age-related changes of evoked potentials. *Neurophysiologie Clinique/Clinical Neurophysiology, 31*(2), 83-103. DOI: 10.1016/s0987-7053(01)00248-9

Patenteu, I., Gawrych, R., Bratu, M., Vasile, L., Makarowski, R., Bitang, A., & Nica, S. A. (2024). The role of psychological resilience and aggression in injury prevention among martial arts athletes.

Frontiers in psychology, 15: 1433835. DOI: 10.3389/fpsyg.2024.1433835

Patenteu, I., Predoiu, R., Makarowski, R., Predoiu, A., Piotrowski, A., Geambașu, A., & Nica, S. (2023). A-trait and risk-taking behavior in predicting injury severity among martial arts athletes. *Frontiers in Psychology, 14*: 1134829. doi: 10.3389/fpsyg.2023.1134829

Predoiu, R. (2010). Percepții complexe – Mişcarea fizică [Complex perceptions - Physical movement] *Discobolul - Revista UNEFS de Cultură, Educaţie, Sport şi Kinetoterapie, 21*(3) 8-14.

Predoiu, R. (2012). *Optimizarea performanței sportive – percepția subliminală, elemente de psihomotricitate, harta mentală* [Optimizing sports performance – subliminal perception, psychomotor dimensions, mental map]. Doctoral thesis, University of Bucharest.

Predoiu, R. (2018). *In mintea campionilor* [Inside the minds of champions]. Discobolul.

Predoiu, R., Makarowski, R., Piotrowski, A., Görner, K., Predoiu, A., Malinauskas, R., Bertollo, M., di Fronso, S., Vazne, Z., Boe, O., Oliveira, R., Miklósi, M., Kovács, K., Ciolcă, C., Badea, D., Vicente-Salar, N., Ciuntea, M. L., & Rawat, S. (2022). Experienced stress among martial arts athletes from selected European Union countries during the 4th wave of the COVID-19 pandemic and the frequency of using coping strategies. *Archives of Budo, 18*, 211–226.

Predoiu, R., Piotrowski, A., Stan, E. A., Ciolacu, M. V., Bitang, A., Croitoru, D., & Cosma, G. (2024). Explicit and indirect, latency-based measure of aggression in striking combat sports. *Frontiers in Psychology, 15*: 1451244. DOI: 10.3389/fpsyg.2024.1451244

Rea, L. M., & Parker, R. A. (2014) *Designing and conducting survey research: a comprehensive guide. 4th Edition*. Jossey-Bass.

Ross, H. E., & Franklin, S. S. (1976) Depth estimation by divers. In E. A. Drew, J. N. Lythgoe & J. D. Woods (Eds.), *Underwater Research* (pp. 191-198). Academic Press.

Scarpina, F., Mauro, A., D'Aniello, G. E., Albani, G., Castelnuovo, G., Ambiel, E., & MacPherson, S. E. (2017). Cognitive estimation in non-demented Parkinson's disease. *Archives of Clinical Neuropsychology, 32*(4), 381-390. DOI: 10.1093/arclin/acx019

Shallice, T., & Evans, M. E. (1978). The involvement of the frontal lobes in cognitive estimation. *Cortex, 14*(2), 294-303. DOI: 10.1016/s0010-9452(78)80055-0

Silverberg, N. D., Hanks, R. A., & Mckay, C. (2007). Cognitive estimation in traumatic brain injury. *Journal of the International Neuropsychological Society, 13*(5), 898-902. DOI: 10.1017/S1355617707071135

Tapia, J. L., Rocabado, F., & Duñabeitia, J. A. (2022). Cognitive estimation of speed, movement and time across the lifespan. *Journal of Integrative Neuroscience, 21*(1): 10. DOI:10.31083/j.jin2101010

U.S. National Science Foundation. (2015). *No fear of falling. Research investigates how infants learn to become wary of heights.* https://new.nsf.gov/news/no-fear-falling

Wąsik, J., & Shan, G. (2015). Kinematics of the turning kick: Measurements obtained in testing well-trained taekwondo athletes. *Archives of Budo, 11*, 61–67.

Yamamoto, N. (2017). Distance Perception. In J. Kreutzer, J. DeLuca, & B. Caplan (Eds.), *Encyclopedia of Clinical Neuropsychology*. Springer.

Zhang, W., Liu, Z., Zhou, L., Leung, H., & Chan, A. B. (2017). Martial arts, dancing and sports dataset: A challenging stereo and multi-view dataset for 3d human pose estimation. *Image and Vision Computing, 61*, 22-39. https://doi.org/10.1016/j.imavis.2017.02.002

Zlate, M. (1999). *Psihologia mecanismelor cognitive* [Psychology of cognitive mechanisms]. Polirom.