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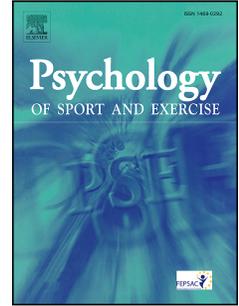
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The Perceptual – Cognitive Skills of Combat Sports Athletes: A Systematic Review

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1 **TITLE: The Perceptual – Cognitive Skills of Combat Sports Athletes: A Systematic**

2 **Review**

3 **Running head: perceptual – cognitive skills in combat sports**

4

5 **Abstract**

6 *The aim of this review is to provide evidence of how practicing combat sports can shape the*
7 *perceptual – cognitive skills of athletes. This is because they must be adept at selecting the relevant*
8 *stimuli in order to anticipate the attack and decide how counterattack their opponent in order to*
9 *achieve victory. A systematic search was conducted on PsycINFO, Scopus and Web of Science via*
10 *the combination of specific keywords. 31 research articles were included. Different aspects of*
11 *perceptual–cognitive skills were analysed, such as complex cognitive skills and basic cognitive*
12 *functions. The investigations were divided by the methods and stimuli used. The results are reported*
13 *in three chapters: one analysed the research conducted with realistic stimuli (videos/pictures),*
14 *another chapter investigated the studies with simulated scenarios, while the last chapter examined*
15 *the basic cognitive functions. Following this is a chapter which, instead, analysed an important*
16 *aspect for future studies: perceptual–cognitive training. The studies revealed better general*
17 *anticipation skills with real and realistic stimuli, and better cognitive functions with regards to*
18 *attention for experts than novices. However, a comprehensive analysis is needed to understand the*
19 *results which emerged from the investigation. Moreover, the review aims to encourage possible*
20 *future research in the topic area.*

21 **Keywords:** cognitive functions; action anticipation; decision-making; perceptual-cognitive
22 training; fight sports

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Introduction

The ability to select stimuli and understand others' actions is crucial in many aspects of our lives: in sport, for example, it has a huge role in winning the game. These abilities underlay the perceptual – cognitive skills that encompass a series of cognitive functions, such as attention, visual discrimination, anticipation, problem solving and decision making (Mann, Williams, Ward & Janelle, 2007; Marteniuk, 1976). In order to achieve their goal, each athlete must be able to shift their attention to the most useful points (e.g. part of the body) to select and extrapolate useful information from the environment in order to understand the future actions of both opponents and teammates. For example, basketball or football players need to quickly understand what is happening around them because they must come up with the best decision in order to select whether they should anticipate their opponent running, or wait for them to come closer to the final goal. To do this, athletes appear to focus, analyse and recognise any subtle kinematic indexes well before any action is taken (Aglioti, Cesari, Romani & Urgesi, 2008; Broadbent, Causer & Williams, 2015; Williams & Ford, 2013).

Combat sports, such as boxing, karate, taekwondo, and judo are not excluded from these demands; as open-skill sports, they are defined as interceptive sports, in which athletes have to coordinate and interact with external opponents either with or without an object (e.g., birdie, balls and blades) (Voss, Kramer, Basak, Prakash & Roberts, 2010). These sports are characterised by sudden environmental changes where each athlete must adapt to new situations in every moment (Lesiakowski, Zwierko & Krzepota, 2013; Voss, Kramer, Basak, Prakash & Roberts, 2010). For these reasons, in addition to strength, endurance and speed, the ability to process intention is crucial to making the appropriate decision to win the match. In these sports, the goal is particularly hard to achieve due to the short distance between the athletes and the different strategies that can be adopted to trick the opponent: for instance, fighters could plan to expose a part of their own body

1 and invite the opponent to hit it, while they are hiding that they are going to release a counterattack
2 (Ottoboni, Russo & Tessari, 2015).

3 In the last 40 years, researchers have extensively studied whether sport practice can enhance the
4 perceptual – cognitive skills both in sport specific and general domains in order to provide evidence
5 of how expertise influences brain functionality (Debarnot, Sperduti, Rienzo & Guillot, 2014). Thus,
6 expertise could affect both the specific and general perceptual – cognitive skills of the athletes.
7 Therefore, this review systematically summarizes the evidence gathered while studying combat
8 sports athletes' perceptual – cognitive skills. The goal was aimed at verifying the superiority of
9 athletes over non-athletes, of experts over novices, and whether there are differences among
10 different combat sports or other sports. Moreover, it was aimed at offering a solid background for
11 further theoretical discussion, while suggesting both experimental and practical implementations.

12

13

14 **Method**

15 According to the Preferred Reporting Items for Systematic Review and Meta-Analysis
16 checklist (PRISMA Moher, Shamseer, Clarke, Gherzi, Liberati, Petticrew et al., 2015), we
17 conducted our systematic search in three databases (Scopus, psycINFO and ISI Web of Science -
18 WoS). In each of them, by following the respective searching rules, we entered the following
19 keywords: perceptual – cognitive skills and the abilities that underpin them such as decision-
20 making, anticipation, visual spatial attention and executive functions. These keywords were further
21 combined with the most popular/practiced combat sports (for the complete keywords list of one
22 database see Table 1).

23 ***Inclusion and exclusion criteria***

24 We limited the search to articles published in *peer-reviewed* journals, written in English
25 language, and published between 1980 and 2019 (January). Moreover, the articles were included if

1 they fell into the subject areas of sport psychology, neuroscience, neurophysiology, or
2 electrophysiology (See Table 1 for the complete research fields included in the search).

3 In total, we found 4407 articles, 1643 from Scopus, 1524 from psycINFO and 1240 from
4 WoS.

5 We excluded the studies which only investigated simple reaction times, as no stimulus or response-
6 related choices are required. We also excluded the studies involving combat sports with a
7 weapon/stick (e.g., fencing or kendo), any developmental studies, all the investigations involved in
8 studying aspects of physiology, medicine and injuries, match analysis, biomechanics, biochemistry,
9 sociology of sport and psychological aspects such as personality traits or motivation in combat
10 sports and all investigations which are unpublished (e.g. theses, dissertations and conference
11 proceedings).

12 In summary, we focused on the sport-related and sport-unrelated perceptual – cognitive skills
13 concerned with combat sports. In particular we attempted to understand if and to what extent
14 perceptual – cognitive skills can be developed through deliberate practice (e.g. difference between
15 different expertise levels and/or non-athletes), and if and to what extent they differ from the skill
16 levels possessed by athletes of other sports. A separate section was dedicated to report the studies
17 which investigated how these skills can be improved through specific training.

18 ***Identification, Screening and Eligibility***

19 Mendeley Software (www.mendeley.com) assisted us in removing any duplicate articles:
20 once removed, 3824 studies remained. Autonomously, each author analysed the list of publications.
21 Specifically, in the first screening, the title and abstract were both examined in order to evaluate
22 whether the article matched the inclusion criteria. If any information was unclear, the entire article
23 was analysed. The first selection consisted of 75 articles for GR and 73 for GO. In the second and
24 third selection process, instead, the full-text articles were examined in order to select the studies
25 which were suitable for the review. The second screening wave included 40 articles for GR and 41
26 for GO. The third (final) wave included 30 articles for each author. In all the screening processes, if

1 an article did not meet the inclusion criteria for both the authors, we discussed, and we reach a
2 neutral decision about the eligibility of the paper.

3 In total, there were 31 articles selected: the article of Nougier, Ripoll & Stein (1989) did not
4 emerge from the search, but it was included in the review as it was cited by Ripoll, Kerlinrzin, Stein
5 and Reine (1995) (See Figure 1 for an overview of the entire screening process).

6 In addition, in order to assess the quality of the study, the items from the Quality Index
7 (Down & Black, 1998) were adopted in this systematic review (Table 2 and 3). The quality
8 assessment was performed by the first author and the decisions were discussed with the other
9 author.

10 *****Insert near here Table 1 and Fig. 1*****

11 **Results**

12 Although combat sports are less popular sports, in the last 30 years a conspicuous number of
13 investigations exploring perceptual – cognitive skills emerged from the systematic examination of
14 literature. On average, they evaluated such perceptual – cognitive skills as anticipation, decision–
15 making, attention, information processing, skill transferability, and training. Most of the studies
16 were composed of cross – sectional and quasi – experimental studies; only two studies investigated
17 the perceptual – cognitive training via interventional paradigms. In particular, the cross-sectional
18 research investigates whether skilled athletes have superior abilities than either less skilled athletes
19 or non-athletes, and in some cases the studies investigated the differences between two different
20 combat sports. On the other hand, the interventional studies tested different forms of training, which
21 were expected to enhance athletes' perceptual – cognitive abilities.

22 The sports selected from our search were the following: karate (research = 17), boxing
23 (research = 8), French boxing (research = 2), taekwondo (research = 4), judo (research = 3), and
24 kung-fu (research = 2).

25 ***Quality assessment***

1 The maximum score that can be obtained was 14 for cross-sectional studies, while 17 was the
2 maximum score for the interventional study (e.g. perceptual – cognitive training). The quality
3 assessment scores revealed a mean score of 82% and the range was 71 – 100%. In the cross-
4 sectional studies, Reporting points 1 – 10 generally meet the satisfactory criteria (Table 2).
5 However, point 6 was the lowest score recorded (31%), where, in general, researchers did not fully
6 control the confounding factors such as age, sociocultural levels and/or level of intelligence of
7 participants, or they did not provide substantial information about them. If we also consider the
8 interventional studies, the percentage decreases further (29%).
9 Only the 66% of the research revealed the real p-value (item 10), and even in this case the
10 percentage decreases after including all the investigations.

11

12 *****Insert near here Table 2 and Table 3*****

13

14 ***Characteristics of the included investigations***

15 The search revealed that perceptual – cognitive skills were investigated by adopting different
16 paradigms and experimental designs. Specifically, researchers adopted specific, sport-related,
17 experimental environment, and the general, sport-unrelated environment. In order to study
18 anticipation, decision-making skills and action recognition, videos/footage and static images were
19 presented, as well as the researchers attempting to replicate the match condition through *in-situ*
20 tasks (e.g. Rosalie & Müller, 2013). Often in these experiments, temporal occlusion paradigms were
21 used (e.g. Williams & Elliott, 1999). Others instead tested the cognitive skills through generic
22 paradigms in order to examine whether the sport activity can produce an enhancement. Also general
23 domains such as stimuli discrimination and attentional abilities were investigated (e.g. Nougier,
24 Ripoll & Stein, 1989).

25 Capitalizing on such variety, in the following sections we present and discuss the studies that
26 come from the search as a function of different experimental settings. This is done in order to

1 understand how the perceptual – cognitive skills vary in regard to the expertise and the stimuli
2 adopted. The first section reports the investigations where videos or pictures (simulated paradigms)
3 were presented; the second section analyses the studies that adopted real scenarios; the third section
4 reports the studies where athletes' cognitive skills were investigated through generic paradigms in
5 order to analyse whether there is a general cognitive enhancement achieved through practice. As
6 already mentioned, a separate section includes the investigations which tested the effect that
7 perceptual – cognitive training has on decision–making and anticipation skills.

8

9 *****Near here Table 4*****

10 ***Investigations on perceptual – cognitive skills in combat sport through simulated scenarios***

11 Nine studies analysed the perceptual – cognitive skills in combat sport by means of realistic
12 paradigms where researchers issued participants with dynamic videos or static pictures within a
13 laboratory setting. Specifically, the studies analysed the sports of *savate* (French boxing; Ripoll,
14 Kerlirzin, Stein & Reine, 1995), boxing (Ottoboni, Russo & Tessari, 2015), karate (Babiloni,
15 Marzano, Infarinato, Iacoboni, Rizza, Aschieri et al., 2010; Del Percio, Marzano, Tilgher, Fiore, Di
16 Ciolo, Aschieri et al., 2007; Del Percio, Rossini, Iacoboni, Infarinato, Aschieri, Lino et al., 2008;
17 Mori, Ohtani & Imanaka, 2002; Petri, Bandow, Salb & Witte, 2018; Williams & Elliott, 1999), and
18 taekwondo (Shi & Li. 2016).

19 Generally, the hypothesis which was assumed at the beginning of each study was focused on
20 verifying the superior skills exhibited by expert athletes when compared to novices or to control
21 participants. The assumptions were often confirmed, but in a few cases no differences emerged
22 among the differing expertise levels.

23 ***Dynamic video stimuli***

24 Ripoll et al. (1995) explored decision–making, kinematic encoding and the visual search
25 strategies of *savate* athletes. The participants (18) were divided into groups according to their
26 expertise (6 experts, 6 intermediates and 6 novices). Participants were immersed in fight scenarios

1 where the opponent performed actions taken from standard French boxing fight actions and the
2 researchers hypothesised that the expert could be able to perform the decision task better than
3 intermediates and novices, while the intermediates should perform the task better compared with
4 the novices. Specifically, there were punch attacks, kick attacks and opening movements in which
5 the model uncovers a body part and feints (an attack-like movement performed to voluntarily
6 deceive the opponent).

7 Each participant was required to respond by moving a joystick to mime the most efficient
8 counteraction. The scenarios were presented both in simple situations, where only two kinds of
9 actions – attacks and openings or attacks and feints – were involved, and in complex situations,
10 where all actions were presented together. In the former, curiously, researchers did not find any
11 differences in terms of accuracy and reaction times among the three expertise levels. The lack of
12 differences among the groups tended to appear controversial but the authors explained the result by
13 assuming each response comes out from the trade-off between velocity and accuracy. Differently,
14 the analysis performed over the complex situations revealed that experts had superior ability
15 compared to the other two groups, and that novices performed better than intermediate athletes. The
16 explanation of this result referred to the difference of expertise between intermediates and novices.
17 The data analysis of eye movements recorded in the complex situations revealed that the upper parts
18 of the body, i.e., head, arm and trunk, were the targets where expert athletes mainly addressed their
19 gaze, whereas novices observed more the lower parts. Again, experts had fewer, but longer,
20 fixations on their target than novices and intermediates. Regarding the location of fixations,
21 outcomes appeared unusual because during the standard training sessions, athletes are used to being
22 advised by their coaches to pay attention to the movements of the opponents' lower limbs. The
23 duration of fixations acquires stronger meaning when it is considered along with the meta-analysis
24 of Mann and colleagues (2007): these authors conclude that fixations and accuracy are correlated:
25 the longer the fixation, the more accurate is the visual information that can be extracted. Moreover,
26 duration apart, there was a further important issue the authors discovered: experts appeared to adopt

1 a visual strategy that was called “Pivot”: each counterpart’s movements were analysed by the
2 observer by anchoring the gaze of the latter over the head of the opponent. In this way, athletes can
3 have a broader perception of the opponent’s body and movements. Such a strategy was supported
4 by considering two complementary perspectives at the same time: the first perspective entails the
5 attention shift described by Posner (1980), the second perspective considers psychophysiological
6 aspects. The former assumes that athletes moved their attention while focusing upon a specific area
7 of interest (Nougier et al., 1989; Posner, 1980), whereas the latter argued that the peripheral vision
8 of the athletes serves to identify the relevant stimuli, which can be analysed by foveal vision
9 afterwards (Ripoll et al., 1995). Recent results confirmed the trade-off between accuracy and
10 reaction times observed by Ripoll and colleagues (1995): higher reaction times correlate with
11 deeper information analysis in experts, but not in novices (e.g., Mann and colleagues 2007; Mori et
12 al., 2002; Ottoboni et al., 2015).

13 Another work of Williams and Elliott (1999) involved videos: the authors recruited karate
14 athletes (8 expert and 8 novices) in order to test their anticipatory skills in both standard
15 experimental and stressful conditions induced by telling participants were involved in a
16 competition. Participants had to respond to different attacks performed by an expert fighter by
17 simulating a defence. Experts demonstrated better anticipation skills than novices in the standard
18 condition, while no differences emerged from the visual search data between the groups. The
19 further visual search analysis revealed that all the athletes fixated more the upper parts of the body
20 (pelvis included) than lower parts (e.g. feet, knees). The data revealed that the stressful condition
21 manipulated the emotional state of the participants, as both groups were more accurate, quicker and
22 more capable of anticipating the opponents than in the normal condition.

23 Initially, the authors did not expect these results; according to their assumption, anxiety would
24 have facilitated the speed of performance at the expense of accuracy (Starkes and Allard, 1983). In
25 the end, the authors explained the findings as a result of the *Processing Efficiency Theory* (Eysenck
26 & Calvo, 1992). This theory argues that athletes maintain a stable performance by increasing their

1 general cognitive effort. Under this light, karate athletes should have kept their performance at a
2 high level by increasing the attentional resources at the cost of mental effort. Under the same
3 stressful conditions, the authors also observed a change in the visual behaviour: the number of
4 fixations increased while the fixations were focused on peripheral body parts, such as arms and
5 fists. The result were said to be related to an increased sensitivity in detecting threatening stimuli
6 (Sarason, 1984), which, in turn, should have both narrowed the central vision (Easterbrook, 1959;
7 Bacon, 1974), and decreased the general attentional control (as later stated by the *Attentional*
8 *Control Theory* of Eysenck et al., 2007).

9 Very similar to the work of Williams and Elliot (1999), Mori and colleagues (2002) analysed
10 the anticipation skills of karate athletes (6 experts and 7 novices) in two experimental settings using
11 video stimuli. In the first setting, participants performed a realistic task, like the ones used by
12 William and Elliott (1999), and both simple and choice reaction times were analysed. Faster
13 anticipation skills were expected in experts but not in novices in both simple and complex reaction
14 times. Simple reaction times were recorded as soon as participants detected a model moving; choice
15 reaction times were recorded as soon as participants identified where the model would have
16 directed his attack. As found by Ripoll and colleagues (1995), choice reaction times were faster in
17 experts than in novices, while no differences emerged between the groups on simple reaction times.
18 In the second experimental setting, the authors only presented 7 frames to participants taken from
19 footage of the previous attacks; even in this case, experts were faster and more accurate than
20 novices. The authors explained the results by accounting for the better extrapolation of information
21 by the experts compared with the less skilled athletes.

22 Differently from the study reported above, which was concentrated with studying attacks and
23 responses, Petri and colleagues (2018) investigated the role of the facial expression on a karate
24 anticipation task. The study arose from what was suggested by both Williams and Elliot, and by
25 Ripoll et al. (1995): expert athletes gaze at the head instead of at other body parts. The authors
26 developed two experiments, one with realistic stimuli and one with a real paradigm. Thus, in this

1 section we report on the experiment with dynamic realistic videos. Ten karate expert athletes
2 participated in the investigation; they had to verbally recognize the type of attack while the face of
3 the attackers was blurred or normal. Participants recognized the attack more accurately while the
4 face was blurred. The fact that, by removing the face of the counterpart, the recognition improved,
5 supports the assumption that facial expressions convey important information affecting sport
6 performance by dragging away participants' attention from important cues.

7 Again, another realistic investigation with dynamic videos analysed the “neural efficiency”, The
8 “neural efficiency” refers to the weaker activation of the fronto-parietal area during known
9 cognitive tasks (e.g., Ruff, Knauff, Fangmeier & Spreer, 2003). In particular, the authors focused
10 their attention on the cortical activation indexed by the alpha event-related
11 desynchronization/synchronization – ERD/ERS. Babiloni and colleagues (2010) matched karateka
12 athletes with different expertise levels (17 expert, 15 amateur) to (11) non-athletes. Participants had
13 to judge the technical and athletic level in a series of karate footage. The neurophysiological data
14 supported the “neural efficiency” as they revealed the weakest activation of the alpha ERD emerged
15 in experts' brains, an intermediate activation was witnessed in amateur karateka and the greatest
16 one in non-athletes' brains.

17 *Static pictures*

18 Four investigations were performed with pictures of body postures aimed at understanding
19 either the attentional and pre-attentional mechanisms featuring boxing athletes (Ottoboni et al.,
20 2015), the relationship between action anticipation and emotion recognition on taekwondo athletes
21 (Shih & Lin, 2016), the brain activity and the “neural efficiency” and the behavioural responses
22 during the visualisation of various sport pictures in karate athletes (Del Percio et al., 2007; Del
23 Percio et al., 2008).

24 A Simon-Like paradigm was used to analyse the attentional and informational processes
25 featuring 13 expert boxing athletes, 8 intermediates boxing athletes and 15 non-athletes while
26 boxing attacks were displayed. In order to test the spatial stimulus-response between boxing

1 athletes, participants were instructed to respond to the colours of the gloves displayed in the
2 pictures, by choosing between two response keys located laterally with respect to the body midline.
3 In line with previous results (Tessari, Ottoboni, Mazzatenta, Merla & Nicoletti, 2012), authors
4 assumed that expert participants coded the punches differently from the less experienced and non-
5 athletes. Results showed that intermediate boxing athletes responded more accurately with the right
6 hand when they saw a left fist, while the left responses were faster in the opposite case, i.e., when
7 right fists were displayed. The control group behaved as the intermediate one, while the expert
8 boxers responded in the opposite way: at the vision of left fists they were more accurately pressing
9 the left response key, while, at the vision of right fists they responded more accurately pressing the
10 right response key. When reaction times were analysed, differences emerged amongst the groups. In
11 particular, the slowest reaction times were recorded for experts, the fastest ones for intermediates,
12 while the control group responded with times in between. By taking into account the accuracy and
13 time trade-off, the authors argued that intermediate boxing athletes, similarly to the *savate* ones
14 tested by Ripoll and colleagues (1995), at the vision of a fist, simulated a defence action (See also
15 Tessari, Ottoboni, Mazzatenta, Merla & Nicoletti, 2012). The explanation echoed what boxing
16 coaches usually say to athletes since the very beginning of training: boxers must learn to defend
17 themselves first. The response velocity suggested that expert athletes took more time as they
18 analysed their opponent's body posture more deeply in order to find the best way to deliver
19 counterattacks.

20 The taekwondo study (Shi & Lin, 2016) tested whether, beyond the abilities to recognise sport
21 specific patterns of movements such as the round kick, combat sports athletes can also recognise
22 emotional expression better than non-athletes and weightlifters. The authors presented to 13
23 taekwondo athletes, 14 weightlifters and 14 non-athletes pictures extrapolated from footage of two
24 taekwondo foot attacks, the "Snatch" Olympic weightlift and the emotional facial expressions (e.g.
25 angry and happy). The videos were performed both by a woman and a man, and participants had to
26 recognize as soon as possible the kind of taekwondo kick (frontal or circular), the good outcomes of

1 the weightlift action and the facial emotion (angry or happiness). Taekwondo athletes and
2 weightlifters were better in recognizing actions congruent with their expertise in terms of reaction
3 times for the taekwondo athletes and accuracy for the weightlifters; no difference emerged from the
4 analysis of facial expressions. However, a significant correlation was found in the taekwondo
5 athletes between the accuracy of taekwondo actions and facial expressions. The authors suggested
6 that the facial emotion might play a role in action recognition as observed in the recent study of
7 Petri and colleagues (2018). The experiment provided further evidence supporting the ability to
8 encode movements starting from static pictures (Blakemore & Decety, 2001).

9 Similarly to the study of Babiloni and colleagues (2010), “neural efficiency” was investigated
10 through pictures by Del Percio et al. (2009). As previously hypothesised by Babiloni (2010), the
11 expert athletes should have showed smaller activation in the alpha-ERD waves. Eleven elite karate
12 athletes, 11 elite fencers and 11 non-athletes had to judge pictures of karate and fencing attacks
13 responding if they were right or left attacks. The behavioural analysis did not reveal any difference
14 among the groups in term of reaction times. On the neurophysiological data, some differences
15 among the groups were found: in contrast to the results obtained by Babiloni et al. (2007), these
16 activations did not account for “neural efficiency”.

17 In line with the previous two studies, but differentiating for what concerns the focus set upon
18 VEP/ERPs (visual/event-related potentials), Del Percio and colleagues (2007) invited 31 karateka
19 (17 experts and 14 novices) and 15 non-athletes to judge pictures of basketball and karate attacks.
20 The authors aim was at testing the behavioural and electrophysiological superiority of experts over
21 the other two classes of participants. Participants were required to judge the direction of attacks.
22 The task was accomplished while VEP/ERPs were recorded: P1, N1, P2, P3 and N2 amplitudes are
23 granted to correlate, respectively, with cognitive performances as visual-spatial attention (P1;
24 Delpont Dolisi, Suisse, Bodino & Gastaud, 1991), visual-discriminative attention (N1; Di Russo,
25 Taddei, Apnile Spinelli, 2006), control inhibit and preparatory activity (P3; Hamon and Seri, 1989;
26 Polich and Lardon, 1997), and sensory discrimination for the motor response (N2; Renault, Ragot,

1 Lesevre & Remond, 1982). It was assumed by Del Percio and colleagues that this would increase
2 the knowledge regarding specific visual stimuli; however, no differences in judgement accuracy
3 emerged among the groups.

4 The neurophysiological data revealed substantial differences among the groups and between the
5 stimuli. The P3 and P4 amplitudes were smaller in elite karateka than amateur karateka.
6 Furthermore, differently from what was showed by non-athletes, in both the karateka groups
7 (amateur and elites), the amplitude of P3 and P4 waves were smaller for karate actions than
8 basketball actions. When compared to basketball action, the karate ones induced higher N2
9 component in elite athletes but not in amateur athletes. The data were controlled with 10 expert
10 fencer athletes where pictures of fencing and karate attacks were presented. The authors recorded
11 similar results to the ones of expert karateka when they watched the fencing attacks compared to the
12 karate actions. The study provided evidence of a relationship between VEP/ERPs modulation and
13 the level of familiarity expert athletes have with the presented pictures.

14 Generally, the studies carried out with realistic stimuli report stronger perceptual – cognitive
15 skills in experts than in intermediates, especially in the case of complex tasks, such a difference
16 fades away when simple tasks were administered. Maybe the simplicity of such task did not engage
17 the experts enough.

18 Another interesting aspect is that athletes have superior performance both with dynamic
19 videos and static pictures. Thus, the athletes are able to perceive movements by observing both
20 body postures and footage (Tessari, Ottoboni, Mazzatenta, Merla, & Nicoletti, 2012; Rosalie &
21 Müller, 2013, 2014). On the other hand, pictures might be unable to fully represent sports'
22 complexity, dynamism and uncertainty of the sport environment where athletes usually play
23 (Abernethy, Burgess-Limerick & Parks, 1994a; Brunswink, 1955 Mann, Williams, Ward & Janelle,
24 2007; Mann et al., 2007) when compared to video. To conclude, the present series of research
25 suggests two aspects: the first is concerned with the use of video or picture stimuli: each of them
26 can be used in the light of the researcher's demand. For instance, pictures are less complicated to

1 manage than dynamic videos as the synchronization with other devices (e.g. Transcranial Magnetic
2 Stimulation - TMS). The second regards electrophysiological evidences: the results yielded so far
3 do not depict a clear picture about athletes' brain functioning, and further investigations are
4 necessary to better understand combat sport athletes' brain functions.

5

6 ***Investigations on perceptual – cognitive skill in combat sport through real paradigms***

7 The new instruments and the technological improvements that have occurred in recent years
8 have allowed the researchers to perform studies using paradigms capitalizing on real settings, i.e.,
9 highly ecological settings where participants perform real counteracts in response to the real
10 opponents' actions.

11 Among the works analysed in the present review, five of them investigated the perceptual –
12 cognitive skills exhibited by karate, taekwondo and judo athletes (Milazzo Farrow, Ruffault &
13 Fournier, 2016; Petri, Lichtenstein, Bandow, Campe, Wechselberger, Sprenger, Kaczmarek et al.,
14 2017; Petri et al., 2018; Piras, Pierantozzi & Squatrito, 2014; Rosalie & Müller, 2013, 2014). The
15 studies involved participants in challenging situations as close as possible to real fights. Essentially,
16 the studies support the findings described in the previous chapter, where we reported that skilled
17 athletes show better anticipation skills and better decision-making performances than intermediates
18 and novices.

19 Rosalie and Müller (2013 & 2014) investigated anticipation abilities in two studies.
20 Moreover, the 2014 study investigated whether such a capability was domain-dependent, i.e., they
21 explored whether athletes can only anticipate the outcomes of the sports they practice, or if the
22 anticipation skill might be extended across other sports. In 2013, the authors required 8
23 international karate athletes (experts), 8 national karate athletes (intermediates) and 7 novices to
24 perform a real, *in-situ* anticipation task. In order to test anticipatory skills, participants wore goggles
25 designed to occlude the vision of the opponent's attacks at four different times. In particular, the
26 occlusion occurred just after the show of the initial stance position (0 ms), i.e., when just small head

1 movements are performed in preparatory phase; after 50 ms from the beginning of the action, i.e.,
2 when the head of the opponent implemented the first preparatory movements, after 100 ms, i.e.,
3 when initial movements of attack were performed, or no occlusion, i.e., leaving the athletes to
4 observe the complete action execution. The task required participants to respond by performing a
5 real movement in order to block the attack. In all the cases but one, the experts showed better
6 anticipation skills than the other two groups. The exception was at 0 ms occlusion: in this case
7 experts performed the task significantly better than novices, but similarly with intermediates.
8 Moreover, the latter were superior to novices in three occlusion conditions, i.e. 50 ms, 100 ms and
9 no occlusion. These results confirmed the higher capability of expert athletes to extrapolate
10 information either from very subtle movement cues or from static pictures representing action
11 postures displayed for a very short time (Mori et al., 2002; Ottoboni et al., 2015; Shi and Li, 2016).

12 In 2014 the same authors, whose work has been just described (Rosalie and Müller, 2014),
13 examined the possibility of transferring the expertise of anticipating the outcomes of a sport that
14 one knows to other, either similar or dissimilar sport domains. This was done in order to understand
15 whether the anticipation processes are principle based, or due to the similarity of the sports tested.
16 Thus, the research was aimed at clarifying what has been so far controversially reported in the
17 literature: i.e., to clarify whether anticipation ability is witnessed across disciplines (Abernethy et al.
18 2003, Williams & Roca, 2017), or whether the transferability regards only some abilities but not
19 anticipation (Gorman, Abernethy & Farrow, 2011). To achieve this goal, karate athletes (6 experts,
20 6 semi-experts and 6 novices) carried out anticipation tasks in both taekwondo and Australian
21 football settings. Further, in order to compare the performances recorded in karate athletes,
22 taekwondo athletes (6 experts and 6 semi-experts) and Australian football players (8 experts and 8
23 semi-experts) were recruited. The authors adopted the same paradigm as Rosalie and Müller (2013)
24 but changing occlusion timing on Australian football actions. In the task involving taekwondo
25 actions, participants had to defend themselves from the attacks, while in the task involving
26 Australian football actions, the participants could decide whether to tackle the opponent or to

1 intercept the ball. The karate athletes' data highlighted the ability to transfer the expertise from the
2 sport athletes to both similar (taekwondo) and dissimilar (Australian football) domains. It emerged,
3 however, that expertise can be transferred more easily across similar contexts (i.e., from karate to
4 taekwondo than from karate to Australian football). These results are in line with the investigation
5 of Williams and Roca (2017) where football players anticipated basketball-related actions more
6 reliably than tennis-related ones.

7 Through another real task, Milazzo and colleagues (2016) investigated the probabilistic
8 choices on decision-making, anticipation and visual search strategies. Fourteen experts and 14
9 novice karate athletes were asked to either defend themselves or counterattack their opponent. To
10 test the probabilistic choice, the opponent performed various karate attacks. However, one specific
11 attack was indicated to occur at regular intervals throughout the test. The authors assumption was
12 that expert athletes might be able to understand the regularity better than novices. Moreover, as a
13 control measure for the behavioural experiment, at the end of the test participants answered various
14 questions about the task in order for the researchers to comprehend the decision making strategies
15 that the participants adopted, and to record whether they noticed different fight sequences (See also
16 Mann, Schaefer and Cañal-Bruland, 2014, for a similar experimental procedure). Results showed
17 that skilled athletes were faster and more accurate than novices in defending themselves or to
18 counterattack. Expert superiority also manifests itself in responding to the specific attack (as they
19 were faster than novices) and in providing verbal insight (experts' reports were more articulated
20 than novices). Also, in this study, the visual search strategies were similar to other investigations
21 (Piras et al., 2014; Ripoll et al., 1995; Williams & Elliot, 1999) where experts had fewer fixations
22 for a longer duration (Mann et al., 2007) than less experienced individuals, and they gazed more at
23 the head and torso while experts were focused more on the forehand and pelvis.

24 A similar study was performed by Petri and colleagues (2018): the authors tested the
25 importance of facial expressions in an anticipation task. As reported in simulated scenarios chapter,
26 the authors based their assumption on the results of Ripoll et al. (1995) and Williams and Elliott's

1 (1999), where the combat sports athletes seem to use a “Pivot” visual strategy in which they anchor
2 their gaze on the head and the upper body of the opponent. The offenders performed attacks while
3 either wearing a ski-mask, ski-mask and sunglasses, or with the face uncovered. The authors
4 performed both a qualitative response and a reaction times analysis. No differences emerged among
5 the response types in any of the three conditions. Differences emerged in the reaction time analysis
6 though: participants were slower when they fought against an actor wearing either the ski-mask or
7 the ski-mask and sunglasses than the case where the opponents’ faces were uncovered. Overall,
8 combined with the simulated study , the results highlighted the fact that facial expressions represent
9 a crucial aspect in combat sports that shift the attention of the observer away from the cues that are
10 crucial in the anticipation process.

11 The visual search behaviour was analysed while seeking for judo’s “first grip”, i.e., the action
12 that athletes use to take down the opponent by grabbing the opponent’s lapel (Piras, Pierantozzi &
13 Squatrito, 2014). Authors investigated the difference between experts and novices in visual search
14 behaviour in terms of spatial position and duration of gaze fixation. Twenty judo athletes with
15 different expertise levels (9 experts and 11 novices) performed attack and defence actions while
16 their eye movements were monitored. In line with what was reported in other works (Milazzo et al.,
17 2016; Ripoll et al., 1995; 2016 Williams and Elliott, 1999), data revealed that an expert’s visual
18 search is characterised by few but long fixations, and that they focussed more on the lapel and the
19 face of the opponent than the rest of the body. On the other hand, in comparison to experts, novices
20 had many but short fixations which were intensely addressed towards the opponent’s arm region
21 (e.g., sleeves and hands).

22 Recently Petri et al. 2017 investigated the anticipation skills through kinematic analysis with a
23 3D-capture analysis tool which is more accurate than other instruments (e.g., high speed video
24 cameras, for a review of benefits and drawbacks of the different motion capture instruments in sport
25 see van der Kruk & Reijne, 2018). They focused on understanding whether the type of attacks and
26 the distance between the fighters are relevant keys in the anticipation processes. Four expert karate

1 athletes fought one against the other (Piras et al., 2014; Rosalie & Müller, 2013, 2014); the
2 attacking fighters were free to perform one of three possible karate attacks: two punches (reverse
3 and jab punch) and one kick (round kick); the defending fighters had to defend themselves or to
4 counterattack. The results showed that the jab punch was the easiest attack to code and react
5 against. The authors argued that such facilitation is given by implicit and subtle preparatory
6 movements that athletes carried out involuntarily (Mori et al., 2002; Rosalie & Müller, 2013, 2014).
7 Summarizing, the research using real-scenarios, both videos and pictures, confirmed that experts
8 showed better perceptual – cognitive skills than non-experts; the former can encode kinematic
9 movements of the opponent far before the attack releases, as they rely on implicit analyses of subtle
10 cues in the body movements of their opponents.

11 ***Investigations on perceptual – cognitive skills in combat sport through generic paradigms***

12 The adoption of generic paradigms is of great importance in studying whether primacy of
13 expert athletes in the sport domain can be generated to general situations (Vestberg, Gustafson,
14 Maurex, Ingvar & Petrovic, 2012). Moreover, contrary to the real and simulated scenarios, the
15 general paradigms are less expensive and require less time (Vestberg et al., 2012).

16 An extensive number of investigations examined the perceptual – cognitive skills of combat
17 sport athletes by means of paradigms such as the Posner-like one, GO/NO-GO task, visual
18 perception speed, and choice reaction time tasks (Bianco, Di Russo, Perri & Berchicci, 2017;
19 Bianco, Ferri, Fabiano, Giorgiano, Tavella, Manili et al., 2011; Bianco, Ferri, Fabiano, Scardigno,
20 Tavella, Caccia et al., 2008; Chen, Song, Chou, Wang & Goodbourn, 2017; Cojocariu and Abalase,
21 2012); Di Russo & Spinelli, 2010; Del Percio, Babiloni, Infarinato, Marzano, Iacoboni, Lizio,
22 2009; Fontani, Lodi, Felici, Migliorini, & Corradeschi, 2006; Guizani, Tenenbaum, Bouzaouach,
23 Kheder, Feki & Bouaziz, 2006; Kim & Petrakis, 1998; Lesiakowski et al., 2013; Mori et al., 2002;
24 Muiños & Ballesteros, 2013, 2014; Nougier, Ripoll & Stein, 1989; Sanchez-Lopez, Fernandez,
25 Silva-Pereyra, Martinez-Mesa & Di Russo, 2014). These experiments were aimed at understanding
26 the basic cognitive processes of skilled fight sport athletes when compared against less skilled

1 athletes or non-athletes. Moreover, they investigated whether the sport practice could have a
2 positive role on cognitive functions. As hypothesised in the research reported in the previous
3 chapters, researchers tended to assume better stimuli discrimination and faster responses in skilled
4 combat sport athletes than in less skilled ones and non-athletes (Voss et al., 2010).

5 Three studies (Chen et al., 2017; Del Percio et al., 2009; Nougier, Ripoll & Stein, 1989)
6 involved posner-like paradigms (1980). Specifically, Nougier and colleagues (1989) analysed the
7 processes of attention orienting in boxing athletes (9 athletes), *savate* (6 athletes), archery (6
8 athletes), penta-athletes (6), and non-athletes (9 students) in order to investigate the existence of
9 differences among the sports, and whether sport could enhance general cognitive skills. Participants
10 had to locate a flash of light as fast as they could which appeared in one of four locations set upon a
11 horizontal line. Additionally, a pre-stimulus cue appeared in 79% of the cases in a position
12 congruent to the one when the following stimulus would appear, in 19% of cases the pre-stimulus
13 was in an incongruent position, while in the remaining 2%, the pre-stimulus was not informative. In
14 the first experiment, boxing athletes and students were tested. The mean of the responses and target
15 processing did not differ between the groups, but both the groups spent more time coding the far
16 stimuli than the near ones (Nicoletti & Umiltà, 1989, Posner, 1980). The difference between near
17 and far stimuli was smaller in boxing athletes than in students, suggesting that boxing athletes are
18 less affected by targets distance. This result confirms what had already been observed in the boxing
19 athletes: they can allocate attentional resources on intermediate areas of the environment in order to
20 develop and understand a general representation of the setting (See the “pivot” strategy described
21 by above, Ripoll & al, 1995; Williams & Elliot, 1999; Piras at al., 2014).

22 In the second experiment, the same task was presented to *savate* athletes, penta-athletes and
23 archery athletes. Results showed the archery group was the fastest group compared to the others.
24 Moreover, as in the first experiment, participants spent more time to respond to the far than the near
25 stimuli (Nicoletti & Umiltà, 1989). The study on visual spatial speed performed by Kim and
26 Petrakis (1998) involved karateka with different levels of expertise (30 experts, 30 intermediates

1 and 35 novices). The study reports that experts demonstrate a better performance compared with
2 both intermediates and novices, while no differences emerged between less experienced athletes
3 and intermediates. According to the authors, the results were given by the best visuo-spatial
4 processes developed by the expert athletes.

5 The study of Del Percio and colleagues (2009) investigated whether karate athletes could
6 discriminate stimuli better than non-athletes under both standard and physically demanding
7 conditions. It involved 14 elite karateka and 11 non-athletes. Participants performed an attentional
8 task where two kinds of trials were presented (valid and invalid trials). The valid trials investigated
9 the endogenous attention, while the invalid trials analysed the reflective attention. The task was
10 performed before a physical effort, after it, or after athletes had completed a recovery period.
11 Results revealed overall slower reaction times for athletes than non-athletes, and significant
12 differences on accuracy: karateka were more accurate than non-athletes in valid trials before
13 physical effort, in invalid trials after the physical exercise, and after the recovery period.
14 Furthermore, athletes were able to maintain high accuracy independent of whether they were
15 assessed before the physical effort or immediately after it, while non-athletes' accuracy on invalid
16 trials decreased across the three conditions. In conclusion, the results showed that fatigue did not
17 affect the cognitive functioning of the karate athletes.

18 Chen and colleagues (2017) presented 38 expert taekwondo athletes, 24 expert karateka and
19 20 non-athletes with an eye – hand coordination task, a perceptual – processing speed task and an
20 attentional control task (e.g. COVAT task – Covert Orienting of Visual Attention). The COVAT is
21 a task very similar to the task adopted in Del Percio's group (2009) and already described. Chen
22 and colleagues (2017) hypothesised differences among the three groups as they assumed differences
23 among the combat sports. The data analysis partially confirmed the assumption: karateka showed
24 better eye – hand coordination than other two groups; while no differences emerged between the
25 performance of the taekwondo group and non-athletes. The COVAT task reported the perceptual
26 processing speed of karate and taekwondo athletes to be faster than non-athletes, while no

1 differences emerged between the two sport groups. An analysis on attentional control, again, did not
2 show differences among the three groups.

3 Expert superiority was called into question by two studies carried out using simple and choice
4 reaction times (Cojocariu & Alabase, 2012; Mori et al., 2002). Mori et al's (2002) expert karateka
5 were faster than novices in locating the stimulus' appearance but not in detecting a circle on the
6 screen. On the other hand, the (eight) expert judokas tested by both Cojocariu and Alabase (2012)
7 did not perform better than the 20 students in either the simple, or the choice tasks.

8 Simple and choice reaction times were also used to compare (10) boxing athletes, (10) tennis
9 players, (10) fencers and (10) table tennis players (Guizani et al. 2006) at rest and after different
10 physical workloads (20%, 40%, 60%, 80% of max power output). All participants were expert
11 athletes, and the authors hypothesised differences among the sports due to their intrinsic
12 differences. Data revealed that, at rest, boxers were faster than table tennis players, but slower than
13 fencers and tennis players in both simple and choice reaction time tasks. After the physical loads,
14 faster reaction times were recorded in fencers and tennis players. The results showed how in this
15 kind of task, fatigue induced an activation of the cognitive system. Conversely, boxing athletes and
16 tennis players showed two different trends that the authors were not able to fully explain.

17 Athletes' superiority is questioned again in a series of studies investigating visual spatial
18 attention. The results reported by Lesiakowski and colleagues (2013) showed no difference in
19 attentional behaviour between (15) expert boxers and (15) non-athletes; Muiños and Ballesteros
20 (2013, 2014), however, showed that the 16 skilled kung-fu athletes they enrolled were able to detect
21 flash stimuli better than the 15 non-athletes when stimuli were presented peripherally at high
22 frequencies. The same authors (2014) recruited 30 skilled judo athletes, 30 skilled karateka and 30
23 non-athletes (all young adults) for one of their studies. Participants performed a task where a dot
24 appeared in different positions on the screen. Athletes showed faster reaction times. Moreover,, as
25 well as responding with the fastest reaction times, the karateka also showed better peripheral vision
26 as they were better able to recognize peripheral stimuli than the other groups. The same authors,

1 again, examined 45 old males (age range between 55 – 68 years old), 15 old expert judo athletes, 15
2 old expert karateka and 15 non-athletes and reported that the karateka and judoka provided faster
3 responses than the non-athletes.

4 In keeping with reporting on studies investigating athletes' attention, Fontani and colleagues
5 (2006) enrolled 18 karate athletes (9 experts and 9 with low experience) and 24 volleyball players
6 (12 experts and 12 with low experience), to test whether they showcased different attentional styles.
7 Participants performed the Zimmerman and Fimm's Attentional battery (1992): which comprises an
8 alert test, a GO/NO-GO task, divided attention test, and a working memory task. In the alert task,
9 the authors recorded simple reaction time, in the GO/NO-GO task, participants had to respond only
10 when a type of stimulus was presented, in the divided attention task, auditory and visual stimuli
11 were presented together, and finally the working memory task where a sequence of stimuli had to
12 be remembered. Results showed that karateka had faster reaction times than the volleyball players.
13 Moreover, within the karateka group, the experts were faster than novices. The superiority
14 disappeared when participants were tested with the Divided Attention task and working memory
15 task: novice volleyball players performed better than the other groups. Quite similar results also
16 emerged in the studies of Bianco and colleagues (2008; 2010). Both the studies investigated
17 simple/choice reaction times, working memory and divided attention. In the study published in
18 2008, professional (n = 27) and amateur (n = 33) boxing athletes differed only in terms of simple
19 reaction times; in the other tasks, they performed similarly. In the 2010 study, the authors compared
20 the performance between female (n = 28) and male (56) boxing athletes, but no differences emerged
21 in any task.

22 Two more studies (Bianco et al., 2017; Di Russo & Spinelli, 2010) adopted a GO/NO-GO
23 paradigm to compare skilled fencers, skilled boxers and control participants both from the
24 behavioural and electrophysiological perspectives. Di Russo and Spinelli (2010) analysed the
25 reaction times, the switch cost (i.e. the difference between NO-GO and GO trials reaction times)
26 and the P1, P2, P3, N1 and N2 waves. The reaction times were similar among the groups, even if

1 fencers reacted significantly faster than non-athletes. However, the switch cost emerged higher for
2 boxers than fencers and non-athletes. The electrophysiological data revealed similar P1 and P2
3 components among the groups and between the conditions (GO and NO-GO). Differences instead
4 emerged for N2, N1 and P3 components. In particular, fencers demonstrated improved visual
5 attention (N1 waves) and in the NO-GO condition a great inhibition of motor responses (N2
6 component). In addition to what the colleagues just mentioned, Bianco and colleagues (2017)
7 analysed two components of readiness: the “Bereitschaftspotential” (BP) and the prefrontal
8 Negativity (pN) waves in 13 fencers, 13 boxing athletes and 13 non-athletes (control group).
9 Whereas BP, whose amplitude is associated to faster responses (Oken & Philips, 2009; Sangals,
10 Sommer, & Leuthold, 2002; Shibasaki & Hallet, 2006), showed greater amplitude in both boxing
11 athletes and fencers than in the control group. pN waves, the amplitude of which reveals the amount
12 of attentional resources involved in the task, showed greater amplitude only in fencers. Moreover,
13 the P1, N1, N2 and P3 waves recorded after the stimulus presentation showed strong amplitudes in
14 the group of fencers. With regards to the behaviour results, reaction times were faster in experts
15 than in the control group, while boxing athletes showed less accuracy than others.

16 Another electroencephalography (EEG) study was developed (Sanchez-Lopez, Fernandez,
17 Silva-Pereyra, Martinez Mesa & Di Russo, 2014) to investigate the superiority of skilled ($n = 12$)
18 martial arts athletes over less skilled ones ($n = 10$). The motor-related cortical potential (MRCP)
19 was recorded during two attentional tasks (e.g. sustained attention task, and transient attention task).
20 It was assumed that the superiority of skilled martial artists would be expressed behaviourally, and
21 in both the positive and negative component of MRCP. The sustained attention task involved
22 showing a list of 600 arrows to participants who had to respond according to their directions. In the
23 transient attentional task, however, participants responded to a target arrow only if three stimuli
24 before the target, a specific arrow appeared. Some differences emerged in the MRCP components
25 but not in the behavioural analysis: experts had larger positive activity and greater posterior
26 negativity before the motor response, compared to less skilled athletes. Differently, in the transient

1 attentional task, the less skilled athletes had a pronounced prefrontal positivity before the motor
2 response, while in the skilled athletes the prefrontal positivity was absent. The sustained attentional
3 task highlighted the better accuracy and efficiency of the experts, furthered by the transient
4 attentional task, which revealed their better efficiency.

5 Summarizing, the general paradigms produced some controversial results. The differences
6 between experts and the less-experienced were not systematically yielded as was found in a recent
7 meta-analysis (2010). However, the results of the studies reported are in line with newer evidence
8 that was not able to prove the superiority of expert athletes (Alves, Voss, Boot, Deslandes, Cossich,
9 Salles, Kramer, 2013; Spitz, Put, Wagemans, Williams & Helsen, 2017). This could be due to
10 reasons as the simplicity of the task, or the low ecology of the stimuli. However, as observed in the
11 electrophysiological investigations, the brain activations appear to differ according to the level of
12 expertise and the sport practiced. On the other hand, some interesting characteristics of combat
13 sport athletes emerged, especially on the attentional paradigms. For example, Nougier, Ripoll and
14 Stein (1989), Mori, Ohtani and Imanaka (2002) and Muiños and Ballesteros (2014) highlighted
15 better attentional processes in combat sport athletes than in the other groups. Moreover, they
16 suggested that athletes demonstrate a more widespread attention capability.

17 Another controversial aspect deals with the differences that emerged between the types of
18 combat sports. Bianco and colleagues (2016), Di Russo and Spinelli (2010) and Muiños and
19 Ballesteros (2013) found very ambiguous differences by comparing combat sports. The results
20 might be due to the interceptive nature of the combat sports, or they may result from the difficulty
21 in sorting athletes according to their level of expertise; however, further investigations are
22 necessary to clarify to what extent athletes and non-athletes differ.

23 ***Perceptual-cognitive training in laboratory and on field***

24 Despite the high interest showed by coaches, physical trainers and researches about the
25 possibility to increase athletes perceptual – cognitive skills and to transfer them from the lab into
26 field, the number of investigations focusing on such a topic are limited and relegated to the hopes of

1 transferring the skills' enhancements from the labs into practice (Abernethy et al. 2012; Broadbent
2 et al. 2015; Farrow, 2013).

3 In two studies, Milazzo and colleagues (2014, 2016) investigated two forms of perceptual –
4 cognitive training. They compared the advantages gained via implicit learning to the ones gained
5 via explicit learning. Implicit learning is defined as the capability to increase one's knowledge
6 without the use of either explicit feedback or verbal explanations regarding the task. On the other
7 hand, explicit learning is described as the learning acquired by providing information about the task
8 (Milazzo, Fourier & Farrow, 2016; Raab, 2003). According to Raab (2003), implicit learning is
9 more useful when the situation features low complexity tasks; when it increases, explicit learning is
10 preferred. Milazzo and colleagues (2014; 2016) developed two training protocols to test the role of
11 different learning types on improvements of anticipation skills of karate athletes. Each research
12 study recruited 18 new athletes: 6 were assessed before and after an implicit training session, 6
13 before and after explicit learning, and 6 before and after standard sessions of training. No
14 differences in pre-training were found among the groups, while post-test outcomes revealed that the
15 group trained implicitly performed the task better and faster than the other groups.

16 Similar results were obtained in Milazzo et al. (2016). The experimental group performed
17 perceptual cognitive training, where participants simulated the responses to various pieces of
18 footage which had been presented to them; the placebo group performed a training task in which
19 they had to punch some flashing stimuli; the control group carried out normal training. The
20 experimental group was more accurate on the realistic task test (i.e., footage) than the other two
21 groups. Moreover, results showed differences on visual search behaviour, where the experimental
22 group provided fewer but longer fixations in the post-test than in the pre-test assessment. This
23 indicated to researchers that the participants showed an improved capability in extrapolating
24 implicit information out of their visual environment (Mann et al. 2007; Williams & Elliott, 1999).
25 Conversely, all participants performed an *in-situ* task in the same manner, and no differences in
26 accuracy emerged between the groups.

1 In conclusion, these few studies highlighted that implicit learning, as compared to explicit
2 learning, is an important factor during the sessions of training as it provides greater benefits in
3 anticipation learning.

4

5

ACCEPTED MANUSCRIPT

1 **Discussion**

2 Combat sports athletes, as other open skill sport athletes, must understand their environment
3 as quickly as possible in order to plan and execute the most appropriate responses to their
4 opponent's actions (e.g. defence, counterattack, or slip away). As these abilities are usually
5 assumed to be stronger in sport athletes as opposed to non-athletes, as well as in experts more than
6 novices, in the present review we audit the research investigating sport-related and sport-unrelated
7 perceptual – cognitive skills in combat sport literature. This is done in order to understand how
8 these skills can vary depending on expertise, and how these skills can be further investigated and
9 trained. The aim is achieved by focusing on such skills as: anticipation, decision-making, visual –
10 spatial attention, and on executive functions, by sorting them according to the research settings (i.e.,
11 realistic videos and picture, real *-in-situ-* situations, and general stimulations).

12 The evidence we gathered by addressing the keywords reported in the introduction reveals
13 that, in combat sports, the superiority of experts (either sportsmen or lay people; Mann et al., 2007;
14 Voss et al., 2010) does not manifest itself to the degree that was expected. Indeed, the better
15 performance reported in responses to real and simulated stimulations were not consistent with the
16 results achieved using general paradigms. In sport related tasks, instead, experts anticipate the
17 actions of their opponents more efficiently than their less skilled counterparts can (e.g. Milazzo et
18 al., 2016; Mori et al., 2002; Ripoll et al., 1995; Williams & Elliot, 1999). Experts were able to
19 encode the movements of the opponents far before their actions executed (Rosalie & Müller, 2014),
20 and the coding was finalized at planning the most appropriate sport-related action (Ottoboni et al.,
21 2015). Some interesting visual search characteristics arise from these studies too. For example, in
22 order to accomplish visual search tasks, combat experts were observed to adopt either a “Pivot”
23 strategy (Milazzo et al., 2016; Piras et al., 2014; Ripoll et al., 1995; Williams & Elliot, 1999), or “a
24 middle” strategy (Nougier et al., 1989). The former consists of anchoring athletes' gaze upon the
25 zones of the opponents' body that are in the middle, between the head and the relevant body parts
26 used to deliver the attack; whereas the latter consists on focusing attention in visual field areas

1 which are in the middle between two consecutive stimulations. Such strategies provide very
2 important advantages: they help athletes in shifting attention towards the areas of the body that are
3 very interesting for either attacks or event-related visual analysis. Such a habit governs the
4 distribution of visual attention in other sports too. In volleyball and in football, for example, athletes
5 pay more attention in areas of space where the action of their sport typically occur (e.g., in the
6 lower and in the upper visual hemi-field, respectively (Castiello & Umiltà, 1997; for a review see
7 Vater, Williams & Hossner, 2019). However, combat experts are used to exert fewer fixations
8 above the sport-key areas, although they look at them for longer (Mann et al., 2007). From these
9 results the eye-tracking appears to be a very important technique because it is capable of providing
10 very interesting insight on processes of information selection and attention (Ripoll et al., 1995;
11 Williams & Elliot, 1999; Deubel & Schneider, 1996; Panchuck, Vine & Vickers, 2015 for an
12 overview). Nowadays, eye-trackers have become extremely affordable and flexible (e.g. Gibaldi,
13 Vanegas, Bex & Maiello, 2017), as they can be adapted to assess human performance in both real
14 and simulated settings (Schack, Bertollo, Koester Maycock & Essig, 2014), as well as in settings
15 using Virtual or Augmented Reality protocol (Stelling-Konczak, Vlakveld, van Gent, Commandeur,
16 van Wee & Hagenzieker, 2018).

17 Conversely to what was observed in real and simulated settings, general paradigms (see Chen et al.,
18 2017, Del Percio et al., 2009; Kim & Petrakis, 1998; Nougier, Ripoll & Stein, 1989) produced
19 outcomes which were in line with the results of Voss and colleagues (2010). These results are not
20 so uncommon, indeed, recent finding tried to analyse the non-sport related perceptual – cognitive
21 skills in football referees, but no difference emerged between the groups tested (Spitz et al., 2017).
22 A reason for this might reside in the fact that the real and simulated studies did not use the same
23 paradigm, they differ a lot depending on the adopted stimuli, dependent variables, and/or groups of
24 tested athletes (e.g. small differences in the expertise). This methodological controversy might be
25 solved by what was proposed by Mori and colleagues (2002): the authors controlled the outcomes
26 which athletes achieved in realistic settings using the outcomes achieved in general settings. These

1 differences could be further debated in order to comprehend whether expertise can enhance
2 cognitive functions, or it is just sport related in general; raising the question whether to continue
3 investigations into these kinds of abilities.

4 However, the entire body of results we reported is not limitation-free. As reported in Table 4,
5 the limits we observed the most regard the number of participants enrolled in the studies, the
6 heterogeneity of the strategies adopted to define athletes' levels of expertise, the gender bias (Bell,
7 Willson, Wilman, Dace & Silverstone, 2006; Solianik, Brazaitis & Skurvydas, 2016, for a review in
8 athletes, see Li, 2014) and the already expressed methodological disparity.

9 One of the main problems in sport psychology research regards the sample size (Schweizer
10 and Furley, 2016): such a limit correlates with a false positive. In the studies we analysed, the
11 sample size problem emerged to affect the paradigms using real and realistic stimuli more than the
12 ones involving general stimuli. Specifically, participants in real and realistic studies were fewer in
13 number than the ones taking part in general paradigm investigations (See Table 4). This limitation
14 might be due to the fact that real and realistic experimental sessions take longer than generic ones,
15 which makes it difficult to find participants. In general, athletes (experts more than others) are
16 unlikely to participate in studies that do not provide them with results that can be used to improve
17 their performance immediately. In the same vein, when experimental sessions take a long time,
18 experts are not keen to participate as they assume that such time is time 'stolen' from their routine
19 (Vater, Roca & Williams, 2015). Another reason for the participants' paucity might be related to the
20 general popularity of combat sports: as these sports do not attract as much attention as soccer,
21 basketball or volleyball; the number of people who practice these sports decrease, consequently.

22 Concerning the athletes' expertise, our literature review reveals that the strategies to sort
23 athletes into expert and less-expert categories are very heterogeneous. Some authors (e.g. Piras et
24 al., 2014) considered people who have been trained for 18 hours overall as being novice athletes.
25 Other authors defined novice athletes as people who had gained two or three years of experience
26 (Del Percio et al., 2007, Ottoboni et al., 2015). On the other hand, expert athletes are labelled as the

1 ones having had more than 8 – 10 years of sport experience (Del Percio et al., 2009; Fontani et al.,
2 2006; Piras et al., 2014), but Mori et al.'s (2002) defined experts as athletes who had 4 – 6 years of
3 experience. It is crystal clear that this heterogeneity must be solved soon. Important indications
4 could come from the ranking adopted in the fighters' leagues (e.g., WKF). Another indication may
5 be the ten years rule (Ericsson, 2006), where experts are identified as having been trained for at
6 least 10000 hours. Furthermore, the definition of intermediate and novice athletes appears more
7 complicated still, because the training level might be confounded by athletes' innate skills. In this
8 light, athletes at the beginning of their career might have a level of performance very similar to
9 intermediates, or on the contrary, athletes with intermediate expertise might have abilities
10 comparable to novices.

11 The entire body of research we reviewed assessed male athletes. Females tend to train
12 themselves in combat sports less often than males. This does not justify the gender bias we
13 observed in the literature search, but it justifies the difficulty in balancing the gender bias we
14 observed.

15 The last limitation we pointed out regards the methodology disparity. Due to the different
16 experimental designs and stimuli adopted, no investigations replicating previous results emerged
17 from our search. Several tasks examined the attentional processes and the cognitive functions, but
18 they evaluated different aspects of them, e.g., attentional task (Nougier et al., 1989), COVAT (Chen
19 et al., 2017), Posner paradigm (Del Percio et al., (2009), Identical Picture Test (Kim & Petrakis),
20 visual – spatial task (Müinos & Ballesteros, 2013, 2014). Thus, the overview the research provided
21 is featured by complexity. The real stimuli and simulated scenarios, instead, tried to examine
22 abilities such as anticipation, action recognition, and decision-making (Mori et al., 2002; Ripoll et
23 al., 1995; Rosaline & Muller, 2014; Williams & Elliott, 1999). Often, this research was concerned
24 with temporal occlusion paradigms, but not adopting standardized actions. Moreover, in these
25 studies, the actors whose actions were used to compose the stimuli array should be able to perform
26 the actions in a perfect way (e.g., with no error or personal addendum); however, this is quite

1 improbable due to the intrinsic variability in the execution of the real actions. In discussing this line
2 of research, realistic paradigms attempt to translate 3-D simulated scenes into a 2-D world.
3 Although the reduction of a visual dimension might bias athletes' perception and responses, the use
4 of such settings guarantees more accurate measurement than the studies in real situations (Mann et
5 al. 2007; Williams & Ericsson, 2005; Witte, Emmermacher, Bandow & Masik, 2012).

6 Aside from the just expressed general limits, the studies focusing on the effect of combat
7 training should further control the bias emerging from the pre and post-test assessment design.
8 According to Gruijters (2016), they should consider the a-priori identification of the variables they
9 use to covariate the experimental outcomes very seriously. Likewise, to avoid a confounding effect,
10 cross – over experimental designs should be encouraged once their limitations have been accepted
11 (Jones and Kenward, 2014).

12 **Conclusion**

13 In light of the outcomes which emerged from the literature search, studies investigating the
14 perceptual – cognitive skills of combat athletes suggest a general superiority of experts compared to
15 non-athletes. The search outcomes also highlighted some limitations, but we are sure these will be
16 overcome in the next years.

17 One of the most promising solutions that can improve combat sport studies regards
18 Virtual/Augmented Reality (Düking, Holmberg & Sperlich, 2018; Vignais, Kulpa, Brault, Presse &
19 Bideau, 2015). The affordability of the technology can help researchers create a new generation of
20 settings capable to balance ecology and measurement control. Another important aspect that will
21 soon receive the appropriate attention in the domain of combat sport is the analysis of the deceptive
22 movements (Güldenpenning Kunde & Weigelt, 2017). Researchers will be able to measure experts'
23 subtle ability to analyse opponents' intentions in order to prevent attacks. In turn, this ability could
24 help in several other domains such as the science of anti-social behaviours (e.g. Cañal-Bruland,
25 2017). Other aspects worth further consideration are the emotional aspects involved in combat
26 sports and how they shape the perceptual – cognitive skills (e.g. Petri et al., 2018; Shi & Li, 2015);

1 and the study of the neural correlates involved in combat sports. In recent years, an increasing
2 number of investigations have been carried out aimed at analysing the neural basis involved in
3 studying sport-related perceptual - cognitive abilities (e.g., Aglioti et al., 2008; Bishop, Wright,
4 Jackson & Abernethy, 2013; Wright, Bishop, Jackson & Abernethy, 2010). Although just a few
5 involved combat sport athletes (Babiloni et al., 2010; Del Percio et al., 2007; Del Percio et al.,
6 2009), neural correlates are important topics in understanding combat behaviour, as they can
7 highlight aspects which behavioural studies are hardly able to measure. As reported in Yang (2015),
8 the functional Magnetic Resonance Imaging technique is reported to be a valid instrument to show
9 how distinctive athletes' skills are. However, in the name of cost-effectiveness, by combining fMRI
10 spatial resolution with the temporal one of EEG and with the precision of TMS, scientific
11 knowledge concerning both general and sport – specific perceptual cognitive skills would further
12 advance (Holmes & Wright, 2017). Another point to be explored concerns the perceptual –
13 cognitive training. This topic could be very useful for the coaches scheduling training sessions. As
14 Harris, Wilson and Vine (2018) reported, the available protocols and instruments are numerous.
15 Vision-training and video-based training aim to increase decision-making and anticipation skills:
16 the first one involves a series of general stimuli; the second one involves simulated situations. The
17 results, especially for what concerns the vision-training, are controversial: further investigations are
18 necessary to understand the effectiveness and efficiency of these training methods. Video-based
19 training, instead, seems to be more useful (Broadbent et al., 2015; Gabbett, Rubinoff, Thorburn &
20 Farrow, 2007), but systematic reviews or meta-analyses are necessary to completely understand the
21 phenomena.

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| Scopus search | | |
|---------------|---|--------|
| ID | Queries/Keywords | Number |
| 1 | (ALL (perceptual OR cognitive AND skill*)) AND (TITLE-ABS-KEY(combat AND sport*)) OR (TITLE-ABS-KEY(martial AND art))OR (TITLE-ABS-KEY(fight* AND sport*)) OR (TITLE-ABS-KEY (boxing)) OR (TITLE-ABS-KEY (judo)) OR (TITLE-ABS-KEY (jiu-jitsu)) OR (TITLE-ABS-KEY (taekwondo)) OR (TITLE-ABS-KEY (karate)) OR (TITLE-ABS-KEY(mixed AND martial AND art*)) OR (TITLE-ABS-KEY (vale AND tudo)) OR (TITLE-ABS-KEY (save OR french AND boxing)) OR (TITLE-ABS-KEY (kung-fu)) OR (TITLE-ABS-KEY (wrestling)) OR (TITLE-ABS-KEY (greco AND roman AND wrestling)) OR (TITLE-ABS-KEY(pankration)) OR (TITLE-ABS-KEY (sanda)) OR (TITLE-ABS-KEY (shoot AND boxing)) AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO(SUBJAREA , "MEDI") OR LIMIT-TO (SUBJAREA , "HEAL") OR LIMIT-TO (SUBJAREA , "PSYC") OR LIMIT-TO(SUBJAREA , "NEUR") OR LIMIT-TO (SUBJAREA , "SOCI") OR LIMIT-TO (SUBJAREA , "ARTS") OR LIMIT-TO (SUBJAREA , "MULT") OR LIMIT-TO (SUBJAREA , "DECI") OR LIMIT-TO (SUBJAREA , "MATE")) AND (EXCLUDE (PUBYEAR , 1979) OR EXCLUDE (PUBYEAR, 1978) OR EXCLUDE (PUBYEAR, 1974) OR EXCLUDE (PUBYEAR, 1967)) AND (LIMIT-TO (LANGUAGE, "English")) | 976 |
| 2 | AND (TITLE-ABS-KEY(combat AND sport*)) OR (TITLE-ABS-KEY(martial AND art))OR (TITLE-ABS-KEY(fight* AND sport*)) OR (TITLE-ABS-KEY (boxing)) OR (TITLE-ABS-KEY (judo)) OR (TITLE-ABS-KEY (jiu-jitsu)) OR (TITLE-ABS-KEY (taekwondo)) OR (TITLE-ABS-KEY (karate)) OR (TITLE-ABS-KEY(mixed AND martial AND art*)) OR (TITLE-ABS-KEY (vale AND tudo)) OR (TITLE-ABS-KEY (save OR french AND boxing)) OR (TITLE-ABS-KEY (kung-fu)) OR (TITLE-ABS-KEY (wrestling)) OR (TITLE-ABS-KEY (greco AND roman AND wrestling)) OR (TITLE-ABS-KEY(pankration)) OR (TITLE-ABS-KEY (sanda)) OR (TITLE-ABS-KEY (shoot AND boxing)) AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO(SUBJAREA , "MEDI") OR LIMIT-TO (SUBJAREA , "HEAL") OR LIMIT-TO (SUBJAREA , "PSYC") OR LIMIT-TO(SUBJAREA , "NEUR") OR LIMIT-TO (SUBJAREA , "SOCI") OR LIMIT-TO (SUBJAREA , "ARTS") OR LIMIT-TO (SUBJAREA , "MULT") OR LIMIT-TO (SUBJAREA , "DECI") OR LIMIT-TO (SUBJAREA , "MATE")) AND (EXCLUDE (PUBYEAR , 1979) OR EXCLUDE (PUBYEAR, 1978) OR EXCLUDE (PUBYEAR, 1974) OR EXCLUDE (PUBYEAR, 1967)) AND (LIMIT-TO (LANGUAGE, "English")) | 410 |
| 3 | (ALL(visual OR spatial AND attention)) AND (TITLE-ABS-KEY(combat AND sport*)) OR (TITLE-ABS-KEY(martial AND art))OR (TITLE-ABS-KEY(fight* AND sport*)) OR (TITLE-ABS-KEY (boxing)) OR (TITLE-ABS-KEY (judo)) OR (TITLE-ABS-KEY (jiu-jitsu)) OR (TITLE-ABS-KEY (taekwondo)) OR (TITLE-ABS-KEY (karate)) OR (TITLE-ABS-KEY(mixed AND martial AND art*)) OR (TITLE-ABS-KEY (vale AND tudo)) OR (TITLE-ABS-KEY (save OR french AND boxing)) OR (TITLE-ABS-KEY (kung-fu)) OR (TITLE-ABS-KEY (wrestling)) OR (TITLE-ABS-KEY (greco AND roman AND wrestling)) OR (TITLE-ABS-KEY(pankration)) OR (TITLE-ABS-KEY (sanda)) OR (TITLE-ABS-KEY (shoot AND boxing)) AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO(SUBJAREA , "MEDI") OR LIMIT-TO (SUBJAREA , "HEAL") OR LIMIT-TO (SUBJAREA , "PSYC") OR LIMIT-TO(SUBJAREA , "NEUR") OR LIMIT-TO (SUBJAREA , "SOCI") OR LIMIT-TO (SUBJAREA , "ARTS") OR LIMIT-TO (SUBJAREA , "MULT") OR LIMIT-TO (SUBJAREA , "DECI") OR LIMIT-TO (SUBJAREA , "MATE")) AND (EXCLUDE (PUBYEAR , 1979) OR EXCLUDE (PUBYEAR, 1978) OR EXCLUDE (PUBYEAR, 1974) OR EXCLUDE (PUBYEAR, 1967)) AND (LIMIT-TO (LANGUAGE, "English")) | 195 |
| 4 | (ALL (reaction AND time*)) AND (TITLE-ABS-KEY(combat AND sport*)) OR (TITLE-ABS-KEY(martial AND art))OR (TITLE-ABS-KEY(fight* AND sport*)) OR (TITLE-ABS-KEY (boxing)) OR (TITLE-ABS-KEY (judo)) OR (TITLE-ABS-KEY (jiu-jitsu)) OR (TITLE-ABS-KEY (taekwondo)) OR (TITLE-ABS-KEY (karate)) OR (TITLE-ABS-KEY(mixed AND martial AND art*)) OR (TITLE-ABS-KEY (vale AND tudo)) OR (TITLE-ABS-KEY (save OR french AND boxing)) OR (TITLE-ABS-KEY (kung-fu)) OR (TITLE-ABS-KEY (wrestling)) OR (TITLE-ABS-KEY (greco AND roman AND wrestling)) OR (TITLE-ABS-KEY(pankration)) OR (TITLE-ABS-KEY (sanda)) OR (TITLE-ABS-KEY (shoot AND boxing)) AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO(SUBJAREA , "MEDI") OR LIMIT-TO (SUBJAREA , "HEAL") OR LIMIT-TO (SUBJAREA , "PSYC") OR LIMIT-TO(SUBJAREA , "NEUR") OR LIMIT-TO (SUBJAREA , "SOCI") OR LIMIT-TO (SUBJAREA , "ARTS") OR LIMIT-TO (SUBJAREA , "MULT") OR LIMIT-TO (SUBJAREA , "DECI") OR LIMIT-TO (SUBJAREA , "MATE")) AND (EXCLUDE (PUBYEAR , 1979) OR EXCLUDE (PUBYEAR, 1978) OR EXCLUDE (PUBYEAR, 1974) OR EXCLUDE (PUBYEAR, 1967)) AND (LIMIT-TO (LANGUAGE, "English")) | 505 |
| 5 | (ALL(attentional AND mechanism)) AND (TITLE-ABS-KEY(combat AND sport*)) OR (TITLE-ABS-KEY(martial AND art))OR (TITLE-ABS-KEY(fight* AND sport*)) OR (TITLE-ABS-KEY (boxing)) OR (TITLE-ABS-KEY (judo)) OR (TITLE-ABS-KEY (jiu-jitsu)) OR (TITLE-ABS-KEY (taekwondo)) OR (TITLE-ABS-KEY (karate)) OR (TITLE-ABS-KEY(mixed AND martial AND art*)) OR (TITLE-ABS-KEY (vale AND tudo)) OR (TITLE-ABS-KEY (save OR french AND boxing)) OR (TITLE-ABS-KEY (kung-fu)) OR (TITLE-ABS-KEY (wrestling)) OR (TITLE-ABS-KEY (greco AND roman AND wrestling)) OR (TITLE-ABS-KEY(pankration)) OR (TITLE-ABS-KEY (sanda)) OR (TITLE-ABS-KEY (shoot AND boxing)) AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO(SUBJAREA , "MEDI") OR LIMIT-TO (SUBJAREA , "HEAL") OR LIMIT-TO (SUBJAREA , "PSYC") OR LIMIT-TO(SUBJAREA , "NEUR") OR LIMIT-TO (SUBJAREA , "SOCI") OR LIMIT-TO (SUBJAREA , "ARTS") OR LIMIT-TO (SUBJAREA , "MULT") OR LIMIT-TO (SUBJAREA , "DECI") OR LIMIT-TO (SUBJAREA , "MATE")) AND (EXCLUDE (PUBYEAR , 1979) OR EXCLUDE (PUBYEAR, 1978) OR EXCLUDE (PUBYEAR, 1974) OR EXCLUDE (PUBYEAR, 1967)) AND (LIMIT-TO (LANGUAGE, "English")) | 54 |
| 6 | (ALL(executive AND function*)) AND (TITLE-ABS-KEY(combat AND sport*)) OR (TITLE-ABS-KEY(martial AND art))OR (TITLE-ABS-KEY (fight* AND sport*)) OR (TITLE-ABS-KEY (boxing)) OR (TITLE-ABS-KEY (judo)) OR (TITLE-ABS-KEY (jiu-jitsu)) OR (TITLE-ABS-KEY (taekwondo)) OR (TITLE-ABS-KEY (karate)) OR (TITLE-ABS-KEY(mixed AND martial AND art*)) OR (TITLE-ABS-KEY (vale AND tudo)) OR (TITLE-ABS-KEY (save OR french AND boxing)) OR (TITLE-ABS-KEY (kung-fu)) OR (TITLE- | 134 |

| | | |
|--|---|-------------|
| | ABS-KEY (wrestling)) OR (TITLE-ABS-KEY (greco AND roman AND wrestling)) OR (TITLE-ABS-KEY(pankration)) OR (TITLE-ABS-KEY (sanda)) OR (TITLE-ABS-KEY (shoot AND boxing)) AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO(SUBJAREA , "MEDI") OR LIMIT-TO (SUBJAREA , "HEAL") OR LIMIT-TO (SUBJAREA , "PSYC") OR LIMIT-TO(SUBJAREA , "NEUR") OR LIMIT-TO (SUBJAREA , "SOCl") OR LIMIT-TO (SUBJAREA , "ARTS") OR LIMIT-TO (SUBJAREA , "MULT") OR LIMIT-TO (SUBJAREA , "DECI") OR LIMIT-TO (SUBJAREA , "MATE")) AND (EXCLUDE (PUBYEAR , 1979) OR EXCLUDE (PUBYEAR, 1978) OR EXCLUDE (PUBYEAR, 1974) OR EXCLUDE (PUBYEAR, 1967)) AND (LIMIT-TO (LANGUAGE, "English")) | |
| | The combination of the Queries #1 #2 #3 #4 #5 #6 was performed through the Boolean operator OR | 1649 |

Table 2. Quality of Assessment

| N | Items |
|--------------------------|---|
| Reporting | |
| 1 | Is the hypothesis/aim/objective of the study clearly described? |
| 2 | Is the underlying theory described? |
| 3 | Are the main outcomes to be measured clearly described in the Introduction or Methods section? |
| 4 | Are the characteristics of the study population included in the study clearly described? |
| 5 ^a | Are the interventions under study clearly described? |
| 6 | Are the distributions of principal confounders in each group of study participants to be compared clearly described? |
| 7 | Are the main findings of the study clearly described? |
| 8 | Does the study provide estimates of the random variability (e.g., standard error, standard deviation, confidence intervals, interquartile range) in the data for the main outcomes? |
| 9 ^b | Is(are) the task(s) clearly described? |
| 10 | Have actual probability values been reported (e.g., 0.035 rather than <0.05) for the main outcomes except where the probability value is less than 0.001? |
| External validity | |
| 11 | Were study participants who agreed to participate representative of the entire population from which they were recruited? |
| 12 | Were the statistical tests used to assess the main outcomes appropriate? |
| 13 | Were the main outcome measures used accurate (valid and reliable)? |
| Internal validity | |
| 14 ^a | Were study participants in the different intervention groups (trials and cohort studies) or Were the cases and controls (case-control studies) recruited over the same period of time? |
| 15 ^a | Were study participants randomized to intervention groups? |
| 16 ^b | Was there a control group of less-expert participants? |
| 17 ^b | Was there a control group of non-athletes, other sport(s) or different gender participants? |

Note: the items were taken from the Quality Index (Downs & Black, 1998) unless otherwise specified. The items (a) were involved only for the interventional studies. Additional items (b) were added in order to control the type of the control group(s) recruited.

Table 3: Quality Assessment scores

| Article | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | Tot | Tot% |
|--|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|-----|------|
| Babiloni, Marzano, Infarinato, Iacoboni et al. (2010) | 1 | 1 | 1 | 1 | - | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | - | - | 1 | 0 | 13 | 93 |
| Bianco, Di Russo, Perri & Berchicci (2017) | 1 | 1 | 1 | 1 | - | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | - | - | 0 | 1 | 12 | 86 |
| Bianco, Ferri, Fabiano, Scardigno et al. (2008) | 1 | 1 | 1 | 1 | - | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | - | - | 1 | 0 | 13 | 93 |
| Bianco, Ferri, Fabiano, Scardigo et al. (2011) | 1 | 1 | 1 | 1 | - | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | - | - | 0 | 1 | 13 | 93 |
| Chen, Song, Chou, Wang & Goodbourn (2017) | 1 | 1 | 1 | 1 | - | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | - | - | 0 | 1 | 12 | 86 |
| Cojocariu and Abalase (2012) | 1 | 1 | 1 | 1 | - | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | - | - | 0 | 1 | 11 | 79 |
| Del Percio, Babiloni, Infarinato, Marzano et al. (2009) | 1 | 1 | 1 | 1 | - | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | - | - | 0 | 1 | 13 | 93 |
| Del Percio, Brancucci, Vecchio, Marzano et al. (2007) | 1 | 1 | 1 | 1 | - | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | - | - | 1 | 1 | 13 | 93 |
| Del Percio, Rossini, Marzano, Iacoboni et al. (2008) | 1 | 1 | 1 | 1 | - | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | - | - | 0 | 1 | 11 | 79 |
| Di Russo & Spinelli (2010) | 1 | 1 | 1 | 1 | - | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | - | - | 0 | 1 | 11 | 79 |
| Fontani, Lodi, Felici, Migliorini, Corradeschi (2006) | 1 | 1 | 1 | 1 | - | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | - | - | 1 | 1 | 13 | 93 |
| Guizani, Tenenbaum, Bouzaouach, Ben Kheder, Feki, Bouaziz (2006) | 1 | 1 | 1 | 1 | - | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | - | - | 0 | 1 | 12 | 86 |
| Kim & Petrakis (1998) | 1 | 1 | 1 | 1 | - | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | - | - | 1 | 0 | 11 | 79 |
| Lesiakowski, Zwierko & Krzepota (2013) | 1 | 1 | 1 | 1 | - | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | - | - | 0 | 1 | 12 | 86 |
| Milazzo, Farrow, Ruffault & Fournier (2016) | 1 | 1 | 1 | 1 | - | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | - | - | 1 | 0 | 11 | 79 |
| Mori, Othani & Imanaka (2002) | 1 | 1 | 1 | 1 | - | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | - | - | 1 | 0 | 10 | 71 |
| Muinos and Ballesteros (2014) | 1 | 1 | 1 | 1 | - | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | - | - | 0 | 1 | 12 | 86 |
| Muinos and Ballesteros (2013) | 1 | 1 | 1 | 1 | - | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | - | - | 0 | 1 | 11 | 79 |
| Nougier, Ripoll & Stein (1989) | 1 | 1 | 1 | 1 | - | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | - | - | 0 | 1 | 10 | 71 |
| Ottoboni, Russo & Tessari (2015) | 1 | 1 | 1 | 1 | - | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | - | - | 1 | 1 | 14 | 100 |
| Petri, Lichtenstein, Bandow, Campe et al. (2017) | 1 | 1 | 1 | 1 | - | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | - | - | 0 | 0 | 10 | 71 |
| Petri, Bandow, Salb & Witte (2018) | 1 | 1 | 1 | 1 | - | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | - | - | 0 | 0 | 11 | 79 |
| Piras, Pierantozzi & Squatrito (2014) | 1 | 1 | 1 | 1 | - | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | - | - | 1 | 0 | 12 | 86 |
| Ripoll, Kerlirzin, Stein & Reine (1995) | 1 | 1 | 1 | 1 | - | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | - | - | 1 | 1 | 12 | 86 |
| Rosalie & Muller (2013) | 1 | 1 | 1 | 1 | - | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | - | - | 1 | 1 | 13 | 93 |
| Rosalie & Muller (2014) | 1 | 1 | 1 | 1 | - | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | - | - | 1 | 1 | 12 | 86 |
| Sanchez-Lopez, Fernandez, Silva- | 1 | 1 | 1 | 1 | - | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | - | - | 1 | 0 | 12 | 86 |

Pereyra, Martinez-Mesa & Di Russo
(2014)

| | | | | | | | | | | | | | | | | | | | |
|----------------------------------|-----|-----|-----|-----|-----|----|-----|-----|-----|----|-----|-----|-----|-----|----|----|----|----|----|
| Shih & Lin (2016) | 1 | 1 | 1 | 1 | - | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | - | - | 0 | 1 | 11 | 79 |
| Williams & Elliott (1999) | 1 | 1 | 1 | 1 | - | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | - | - | 1 | 0 | 11 | 79 |
| Items | 29 | 29 | 29 | 29 | | 9 | 24 | 28 | 28 | 19 | 27 | 29 | 29 | | | 14 | 19 | | |
| Items % | 100 | 100 | 100 | 100 | | 31 | 83 | 97 | 97 | 66 | 93 | 100 | 100 | | | 48 | 66 | | |
| Average score | | | | | | | | | | | | | | | | | | 12 | 84 |
| Milazzo, Farrow & Fourier (2014) | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 13 | 77 |
| Milazzo, Farrow & Fourier (2016) | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 12 | 71 |
| Items | 2 | 2 | 2 | 2 | 2 | 0 | 2 | 2 | 2 | 0 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | | |
| Items % | 100 | 100 | 100 | 100 | 100 | 0 | 100 | 100 | 100 | 0 | 100 | 100 | 100 | 100 | 50 | 0 | 0 | | |
| Average score | | | | | | | | | | | | | | | | | | 13 | 74 |
| Total average score | | | | | | | | | | | | | | | | | | 12 | 84 |

Note: 1 – yes, 0 – No/unknown.

Summary of the main results on perceptual – cognitive skills of combat sports athletes.

| Author(s) | Sport(s) | Number of participants* | Age range (y.o.); mean – sd/se | Expertise | Situation | Task(s) | Dependent variable(s) | Main results |
|--|----------|--|---|---|--|--------------------------------------|----------------------------------|--|
| Realistic paradigms | | | | | | | | |
| Babiloni, Marzano, Infarinato, Iacoboni, Rizza, Aschieri, Cibelli, Soricelli, Eusebi & Del Percio (2010) | Karate | 17 EXP karateka (7 females) 15 NOV karateka (8 females) 11 non-athletes | 20–33; 23.8 ± 1 17–33; 21.5 ± 2 17–35; 24.6 ± 1.4 | National and International level 2–5 yrs. of experience No experience | Realistic (picture) | Action recognition | EEG-alpha ERD | Data revealed a minor activation of the alpha ERD for the expert, middle for amateur karateka and greater activation for non-athletes. |
| Del Percio, Brancucci, Vecchio, Marzano, Pirritano, Meccariello, Padoa, Mascia, Giallonardo, Aschieri, Lino, Palma, Fiore, Di Ciolo, Babiloni, Eusebi (2007) | Karate | 17 EXP karateka (7 females) 14 NOV karateka (4females) 15 non-athletes | 19–31; 23.6 ± 1.1 18–26; 21 ± 0.6 18–26; 28.8 ± 1.1 | More than 10 yrs. 2–3 yrs. No-experience | Realistic (pictures) | Anticipation task | EEG – VER/ERPs Reaction times | Behavioural results RT: No-differences among the groups EEG – VER/ERPs Non-athletes: no-differences between the pictures presented P3 and P4 were lower in NOV for basket and karate attacks P3 and P4 were lower in EXP for basket and karate attacks, but an increment on N2 for karate attacks was found |
| Del Percio, Rossini, Marzano, Iacoboni, Infarinato, Aschieri, Lino, Fiore, Toran, Babiloni, Eusebi (2008) | Karate | 11 EXP karateka (5 females) 11 EXP fencers (8 females) 11 non-athletes (5 females) | 19–31; 25.3 ± 1.5 19–33; 25.5 ± 1.5 21–34; 29.6 ± 1.2 | More than 10 yrs. More than 10 yrs. No experience | Realistic | Action recognition | EEG-alpha ERD Reaction times | Behavioural results RT: No-differences among the groups EEG – alpha ERD Some difference among the groups were found, but the results of the activations were not able to explain completely the “neural efficiency”. |
| Mori, Othani & Imanaka (2002) | Karate | 6 EXP 6 NOV | 19–22; 21 21–43; 28 | 4–6 yrs. No-experience | Realistic (footages) & general paradigms | Anticipation task & General paradigm | Reaction times Accuracy | Realistic (footages) task Simple RT: EXP = NOV Choice RT: EXP < NOV Occlusion task RT: EXP < NOV Accuracy: EXP > NOV General paradigm Simple RT: EXP = NOV Choice RT: EXP < NOV Reaction times: EXP > non-boxing athletes and INT INT < non-boxing athletes |
| Ottoboni, Russo & Tessari (2015) | Boxing | 13 EXP 8 NOV 15 non-boxing ath. | 18–32; 25.5 17–31; 22.8 21–33; 24.5 | Matches: 20 – 111 1 – 14 No-experience | Realistic (pictures) | Simon – Like paradigm | Reactions times Accuracy | Behavioural differences at the vision of boxing stimuli. For example, expert athletes seemed to try to counterattack, while the novices and non-athletes seemed to be putting in defensive actions. |

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|---|-----------|--|---|---|---|---|--|--|
| Petri, Bandow, Salb & Witte (2018) | Karate | Study A 10 karateta (5 females) | 19.5 ± 5.8 | National and International level | Study A Realistic (footages) Study B <i>In-situ</i> | Action recognition/ Anticipation | Verbal reports Accuracy Reaction times | Study A Athletes were able to better understand better the action when the face of the opponent was blurred compared with normal face. Study B Athletes responded faster when the attackers wore a ski mask or ski mask and sunglasses than the attack was performed in normal condition. |
| | | Study B 12 karateka (6 females) | 20.6 ± 6.4 | | | | | |
| Ripoll, Kerlirzin, Stein & Reine (1995) | Savate | 6 EXP 6 INT 6 NOV | 22–33; 27.3 20–25; 23.8 22–33; 26.3 | French-nat. team First level class No- competition | Realistic (footages) | Anticipation & Decision making task | Fixations Reaction times Accuracy | Complex task Accuracy: EXP > INT e NOV; NOV > INT RT: no-difference among the groups Visual search behaviour: Experts observed upper part of the body, in particular head. |
| Shih & Lin (2016) | Taekwondo | 14 TKD 14 weight-lifters 14 non-athletes | 19–23; 20.8 ± 1.4 20–24; 21.8 ± 1.5 19–23; 20.9 ± 1.2 | Athletes: 8.4yrs s=2.9 Non-athletes: No-experience | Realistic (pictures) | Action recognition/ Anticipation task | Reaction times Accuracy | Realistic (TKD pictures) TR: TKD < Weightlifters e control group Weightlifting Accuracy: Weightlifters > TKD athletes and control group Emotional pictures TKD Athletes were more accurate in the early stages of vision than weightlifter and control group. High correlation in TKD athletes between the anticipation of taekwondo actions and of emotional facial expressions. |
| Williams & Elliott (1999) | Karate | 8 EXP 8 NOV | 22.0 ± 2.3 23.5 ± 4.6 | 5.6 yrs. s = 4.6 No-experience | Realistic (footages) | Anticipation task | Fixations Reaction times Accuracy | Low anxiety RT: EXP < NOV Accuracy: EXP > NOV High anxiety RT: EXP < NOV Accuracy: EXP > NOV Visual search behaviour: no-differences between the groups and high anxiety induced changes on visual search behaviour in both the groups. |
| Real paradigms (in-situ tasks) | | | | | | | | |
| Milazzo, Farrow, Ruffault & Fournier (2016) | Karate | 14 EXP 14 NOV | 25.6 ± 2.5 27.4 ± 1.4 | International competitions 1.6 yrs. ± 0.7 | <i>In situ</i> | Anticipation task | Reaction times Accuracy Fixation | RT: EXP < NOV Accuracy: EXP > NOV Repeated action: better anticipation for EXP than NOV Visual Search Behaviour: EXP fewer fixations of longer duration EXP gazed head and trunk NOV gaze head, trunk and fore hand Verbal responses after the task, EXP were more accurate and detailed than NOV |
| Piras, Pierantozzi & Squatrito (2014) | Judo | 9 EXP | 26.89 ± 6.68 | ±16 yrs. of | <i>In situ</i> | Anticipation task | Fixations | Visual search behaviour: EXP less fixations of longer duration. NOV more fixations |

| | | | | | | | | | |
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| | | 11 NOV | | experience | | | | of short duration. EXP gazed the face and lapel while NOV gazed hand and arm. | |
| Petri, Lichtenstein, Bandow, Campe, Wechselberger, Sprenger, Kaczmarek, Emmermacher & Witte (2017) | Karate | 4 EXP | 23.64 ± 1.80) | 14 hrs (white belt) | International competitions | <i>In situ</i> | Anticipation task | Reaction time | The jab punch was easier to recognize compared to the other attacks, especially in firsts phases of the movement. |
| Rosalie & Muller (2013) | Karate | 8 EXP 8 INT 7 NOV | 19–28; 23.1 ± 3.31 18–46; 28.5 ± 11.86 18–34; 22.1 ± 5.16 | Aus. Nat. team National experience No-experience | | <i>In situ</i> | Anticipation task | Accuracy | Occlusion: 0 ms: EXP = INT; EXP > NOV 100 ms: EXP > NOV & INT; NOV=INT 150 ms: EXP > NOV& INT; INT > NOV no occlusion: EXP > NOV& INT; INT > NOV |
| Rosalie & Muller (2014) | Karate Taekwondo Australian football | 6 karateka EXP 6 karateka INT 6 karateka NOV 6 TKD EXP 6 TKD INT 8 Aus. football EXP 8 Aus. football NOV | 19–28; 23.61 ± 3.61 19–49; 30.6 ± 11.95 18–26; 20.5 ± 3.02 22–39; 28.5 ± 6.80 19–35; 29 ± 6.36 21–23; 21.63 ± 0.74 18–23; 20.4 ± 1.95 | Aus. Nat team National experience No-experience Aus. Nat. team National experience Aus. Nat. team No-experience | | <i>In situ</i> | Anticipation task | Accuracy | TKD task Accuracy: Karateka EXP & INT = TKD, EXP & INT; Karateka EXP & INT > NOV Australian football task Occlusion 400 ms: Karateka EXP = Australian football EXP |

Generic paradigms

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|--|---------------------|--|--|--|-------------------|--|---|---|
| Bianco, Di Russo, Perri & Berchicci (2017) | Boxing Fencing | 13 boxing athletes 13 fencers 13 control group | (29.4 ± 2.4) (25.5 ± 1.5) (28.5 ± 1.9) | Athletes: ± 15 yrs. of experience Physically active | General paradigm | GO/NO-GO task | Reaction times Accuracy ERP: BP, pN, P1, P2, P3 | Behavioural results RT: Athletes < Control group; Accuracy: Boxers < fencers and control group Electrophysiological results EEG - ERP BP: greater amplitude for boxing athletes and fencers pN: greater only in fencers P1, N1, N2, P3: greater only in fencers |
| Bianco, Ferri, Fabiano, Giorgiano, Tavella, Manili, Fainas, Palmieri, Zeppilli (2011) | Boxing | 28 females 56 males | 25.0 ± 5.5 25.19 ± 5.6 | 2.1 ± 2.1 2.7 ± 3.8 | General paradigms | Choice reaction times Working memory Divided Attention | Reaction times Accuracy | No differences between the groups |
| Bianco, Ferri, Fabiano, Scardigno, Tavella, Caccia, Manili, Faina, Casasco & Zeppilli (2008) | Boxing | 27 EXP boxing athletes 33AMATEUR boxers | 29.5 ± 4.19 20.3 ± 4.77 | ~ 15 years of experience ~ 6 years of experience | General paradigms | Choice reaction times Working memory Divided Attention | Reaction times Accuracy | No differences between the groups |
| Chen, Song, Chou, Wang & Goodbourn (2017) | Karate Taekwondo | 38 TKD athletes (16 females) 24 Karateka | 19.9 ± 1.2 18.9 ± 0.9 | Athletes: more than 8 yrs. of experience | General paradigm | COVAT (Posner – like paradigm) Eye – hand | Reaction times | Eye – hand coordination Karateka showed better eye-hand coordination than other two groups; no-differences between taekwondo athletes and |

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|--|---|--|---|---|-------------------|---|--|---|
| | | (9 females) 35 non-athletes (20 females) | 20.6 ± 1.5 | Non-athletes: No-experience | | coordination | | non-athletes. COVAT task Karate and taekwondo athletes performed better than non-athletes |
| Cojocariu and Abalase (2012) | Judo | 8 judokas 20 students | 21 – 25 18 – 24 | More than 10 yrs No-experience | General paradigm | Simple & choice reaction times task | Reaction times | No-differences between the groups. |
| Di Russo & Spinelli (2010) | Boxing Fencing | 12 boxing athletes (4 females) 12 fencers (5 females) 12 non-athletes (5 females) | 28.1 ± 5.5 26.3 ± 6.5 25.8 ± 3.8 | 13.3 yrs. of experience 10.5 yrs. of experience | General paradigm | GO/NO-GO task | Reaction times Accuracy ERP: P1, P2, P3, N1 and N2 | Behavioural results RT: fencers < non-athletes; boxers = non-athletes, boxers = fencers Switch cost boxing athletes > fencers and non-athletes Electrophysiological results EEG - ERP Fencers had improved visual attention (N1 waves) an inhibition of motor responses (N2 component) |
| Del Percio, Babiloni, Infarinato, Marzano, Iacoboni, Lizio, Aschieri, Cè, Rampichini, Fanò, Veicsteinas, Eusebi (2009) | Karate | 14 EXP karateka (6 females) 11 non-athletes (5 females) | 19–32; 24.1 ± 1.3 21–27, 23.5 ± 0.6 | More than 10 yrs. No-experience | General paradigm | Posner – like paradigm | Reaction times & Accuracy | Valid trials Before physical effort Accuracy: karateka > non-athletes Invalid trials After physical effort Accuracy: karateka > non-athletes After recovery period Accuracy: karateka > non-athletes |
| Fontani, Lodi, Felici, Migliorini & Corradeschi (2006) | Karate Volleyball | 19 karateka 9 EXP 9 NOV 24 volleyball players 12 EXP 12 NOV | (31 ± 5) (32 ± 5) (28 ± 5) (19 ± 2) | Expert: more than 8 yrs. Less expert: less than 8 yrs. | General paradigms | Zimmerman and Fimm's Attentional Test: Alert test Visual – spatial attention GO/NO-GO task Divided Attention task Working memory task | Reaction times Accuracy | Alert test – simple reaction times EXP & NOV Karateka < EXP & NOV volleyball players EXP Karateka < NOV karateka Divided Attention & Working memory test NOV Karateka better performance than EXP karateka EXP volleyball players slower than NOV volleyball player but performed better the tasks than less skilled |
| Guizani, Tenenbaum, Bouzaouach, Kheder, Feki & Bouaziz (2006) | Boxing Fencing Tennis Table tennis | 10 boxing athletes 10 fencers 10 table-tennis p. 10 tennis players | (18 ± 1.05) (19.1, ± 2.99) (19.2 ± 2.29) (19 ± 1.94) | National team athletes | General paradigms | Simple & choice reaction times task | Reaction times | Reaction times <i>At rest:</i> table tennis players were the slowest compared to other groups. Fencers were quicker than boxing athletes. Fencers = tennis players. <i>After workloads</i> Faster reaction times for fencers and tennis players. Boxing and table tennis players showed a particular trend. Expert athletes had better visuo-perceptual abilities compared with intermediates and novices. |
| Kim & Petrakis (1998) | Karate | 30 EXP (15 females) | Females: 23.1 | Black belt | General paradigm | Identical Picture Test | Accuracy | |

| | | | | | | | | |
|--|--|---|--|---|-------------------|--|----------------|---|
| | | 30 INT (15 female) 35 NOV (15 females) | Males: 22.6 | Blue belt White belt | | | | No differences between intermediates and novices were found. |
| Lesiakowski, Zwierko & Krzepota (2013) | Boxing | 15 EXP (5 females) | (20.4 ± 5.2) | National team athletes | General paradigms | Visual – spatial attention task | Reaction times | No-differences between the groups |
| | | 15 non-boxing athletes | (21.9 ± 1.96) | No-experience | | | | |
| Muiños & Ballesteros (2014) | Karate Judo | Experiment 1 30 young judokas 30 young karateka 30 young non-athletes | 21–32 (27.6 ± 3.8) 19–34 (25.3 ± 4.8) 19–28 (23.5 ± 4.8) | Athletes: International | General paradigms | Visual – spatial attention task | Reaction times | Reaction times Young athletes: Non-athletes > karateka > judo athletes judo athletes < non-athletes Karateka showed better peripherally vision than other groups Old athletes: Old judokas and karateka < old non-athletes |
| | | Experiment 2 15 old judokas 15 old karateka 15 old non-athletes | 60–67 (64.1 ± 3.6) 55–65 (63.7 ± 3.2) 55–68 (64.7 ± 4.3) | Old athletes: More than 10 yrs No-experience | | | | |
| Muiños & Ballesteros (2013) | Kung-fu | 16 kung-fu athletes 15 non-athletes | 20–39 (30.7 ± 5.73) 22–35 (30.3 ± 4.33) | 10 yrs experience No-experience | General paradigms | Visual – Spatial attention task | Reaction times | Reaction times Kung-fu athletes < non-athletes for stimuli with high frequencies of presentation and at periphery |
| Nougier, Ripoll & Stein (1989) | Boxing Savate | 9 boxing athletes EXP 9 students 6 savate athletes 6 pentathletes 6 archers 6 control group | 20–25 | | General paradigms | Attentional task | Reaction times | Boxing athletes less affected by target eccentricity, they showed a better spatial |
| Sanchez-Lopez, Fernandez, Silva-Pereyra, Martinez-Mesa & Di Russo (2014) | Martial arts athletes: judo, taekwondo and kung-fu | 12 EXP athletes 10 NOV athletes | 25.5 ± 10.6 24.3 ± 9.7 | More than 5 years practice Less than 1 year practice | General paradigms | Sustained and Transient Attention task | MRCP Accuracy | Behavioural analysis: No differences emerged between the groups in both the tasks. MRCP analysis: Sustained Attention analysis: Larger positive activity and greater posterior negativity before the motor response for experts compared to less skilled athletes. Transient Attention analysis: Less skilled athletes had a pronounced prefrontal positivity than before the motor response, while in the skilled athletes was absent. |
| Perceptual – cognitive training | | | | | | | | |
| Milazzo, Farrow & | Karate | 18 EXP: | 23–31; 26.4 ± 3.1 | Average of 10 yrs. | Realistic | Perceptual – | Reaction | The experimental group show enhancements in reaction |

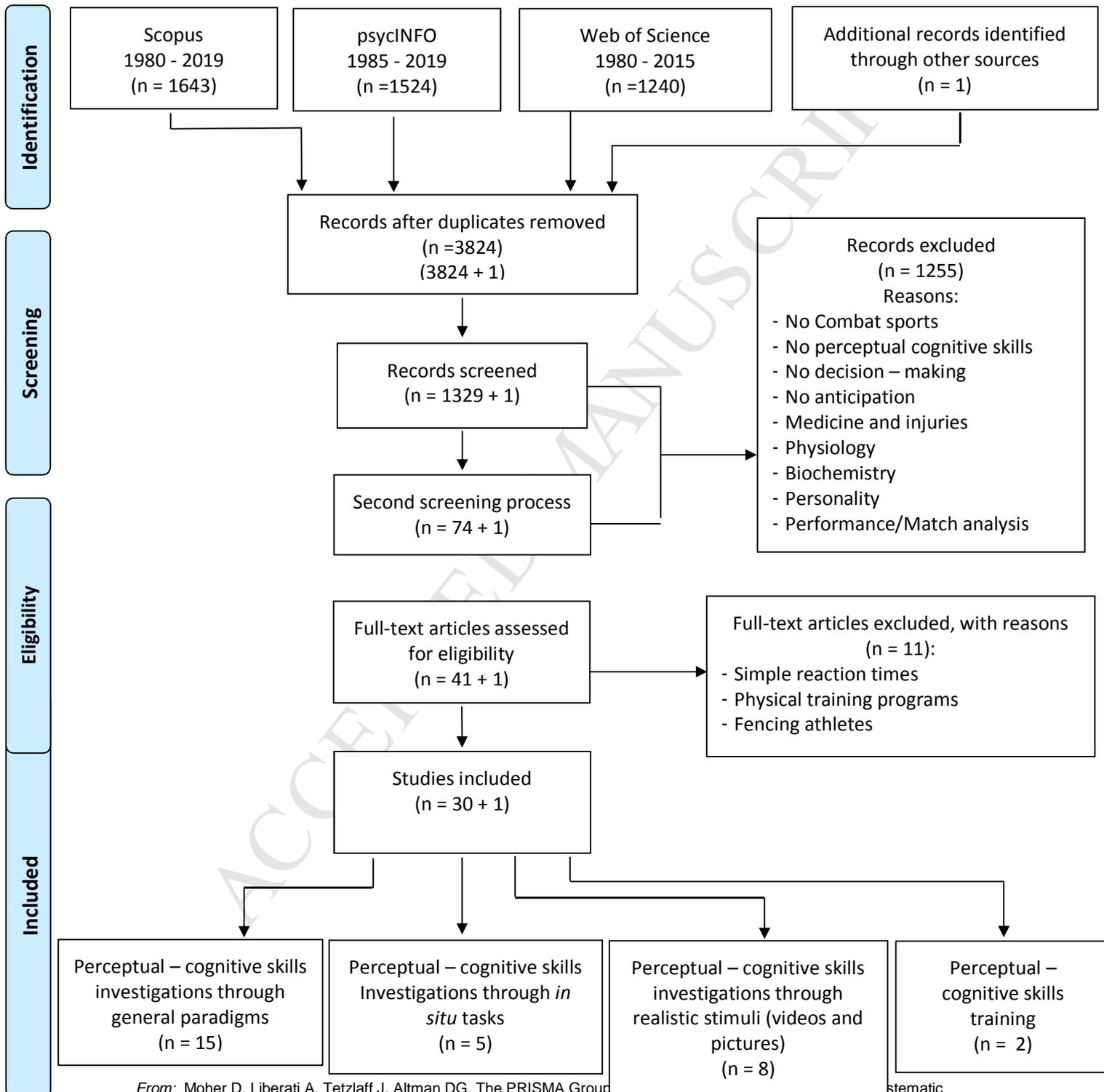
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|----------------------------------|--------|--|-------------------|---------------------------------|---|--|----------------------|---|
| Fourier (2014) | | 6 experimental group 6 placebo group 6 control group | | experience | (footages) | cognitive training & anticipation test | times Accuracy | times and accuracy compared to the other two groups. |
| Milazzo, Farrow & Fourier (2016) | Karate | 18 females EXP: 6 experimental group 6 placebos 6 control group | 14–18; 15.7 ± 1.2 | Average of 8 yrs. experience | Realistic (footages) & <i>In situ</i> | Perceptual – cognitive training & Anticipation test | Fixation Accuracy | Realistic task: Experimental group showed enhancements in reaction times and accuracy than the other two groups. Moreover, the experimental changing its visual search strategy after the training, compared to the others. Accuracy on <i>in-situ</i> task: no-differences among the groups |

Table 4: EXP = experts, INT = intermediate and near - experts, NOV = novices, TKD = taekwondo, RT = reaction times, ERP= Event-Related Potentials VERP = Visual Event-Related Potentials, EEG = electroencephalography, MRCP = motor-related cortical potential.

*Wilcoxon rank sum test revealed that the authors recruited less participants in the studies with real and realistic paradigms compared with generic paradigm (22.7±12.8 VS 51.2±26.9, $W < .00$).



Perceptual – cognitive skills PRISMA Flow Diagram



From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. <http://doi.org/10.1371/journal.pmed1000097>

Highlights

The present review on the perceptual – cognitive skills of the combat sport athletes highlighted the following results:

- Different kind of stimuli were involved to investigate the perceptual – cognitive skills of the combat sports athletes (e.g. real (*in-situ*) task; realistic stimuli e.g. footages and images and general stimuli e.g. general paradigm such as Posner and other attentional paradigms).
- Real and Realistic stimuli showed similar results in term of anticipation and decision-making skills where the expert athletes had better perceptual -cognitive skills
- The results on general stimuli, instead, were quite controversial, for instance, no difference emerged from the expert and less expert in simple reaction time task, while this happened for complex reaction time tasks. This could be explained with high ability of the combat sport athletes to react to the complex situations.