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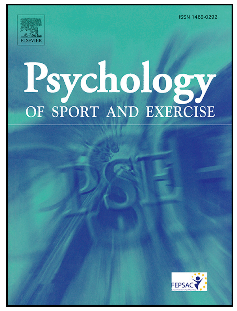

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The Perceptual – Cognitive Skills of Combat Sports Athletes: A Systematic Review

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Running head: perceptual – cognitive skills in combat sports

Abstract

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

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

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

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

Method

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

Inclusion and exclusion criteria

We limited the search to articles published in *peer-reviewed* journals, written in English language, and published between 1980 and 2019 (January). Moreover, the articles were included if they fell into the subject areas of sport psychology, neuroscience, neurophysiology, or electrophysiology (See Table 1 for the complete research fields included in the search).

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

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

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

Identification, Screening and Eligibility

Mendeley Software (www.mendeley.com) assisted us in removing any duplicate articles: once removed, 3824 studies remained. Autonomously, each author analysed the list of publications. Specifically, in the first screening, the title and abstract were both examined in order to evaluate whether the article matched the inclusion criteria. If any information was unclear, the entire article was analysed. The first selection consisted of 75 articles for GR and 73 for GO. In the second and third selection process, instead, the full-text articles were examined in order to select the studies which were suitable for the review. The second screening wave included 40 articles for GR and 41 for GO. The third (final) wave included 30 articles for each author. In all the screening processes, if an article did not meet the inclusion criteria for both the authors, we discussed, and we reach a neutral decision about the eligibility of the paper.

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

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

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

Results

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

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

Quality assessment

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

Only the 66% of the research revealed the real p-value (item 10), and even in this case the percentage decreases after including all the investigations.

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

Characteristics of the included investigations

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

Capitalizing on such variety, in the following sections we present and discuss the studies that come from the search as a function of different experimental settings. This is done in order to understand how the perceptual – cognitive skills vary in regard to the expertise and the stimuli adopted. The first section reports the investigations where videos or pictures (simulated paradigms) were presented; the second section analyses the studies that adopted real scenarios; the third section reports the studies where athletes' cognitive skills were investigated through generic paradigms in order to analyse whether there is a general cognitive enhancement achieved through practice. As already mentioned, a separate section includes the investigations which tested the effect that perceptual – cognitive training has on decision–making and anticipation skills.

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

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

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

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

Dynamic video stimuli

Ripoll et al. (1995) explored decision–making, kinematic encoding and the visual search strategies of *savate* athletes. The participants (18) were divided into groups according to their expertise (6 experts, 6 intermediates and 6 novices). Participants were immersed in fight scenarios where the opponent performed actions taken from standard French boxing fight actions and the researchers hypothesised that the expert could be able to perform the decision task better than intermediates and novices, while the intermediates should perform the task better compared with the novices. Specifically, there were punch attacks, kick attacks and opening movements in which the model uncovers a body part and feints (an attack-like movement performed to voluntarily deceive the opponent).

Each participant was required to respond by moving a joystick to mime the most efficient counteraction. The scenarios were presented both in simple situations, where only two kinds of actions – attacks and openings or attacks and feints – were involved, and in complex situations, where all actions were presented together. In the former, curiously, researchers did not find any differences in terms of accuracy and reaction times among the three expertise levels. The lack of differences among the groups tended to appear controversial but the authors explained the result by assuming each response comes out from the trade-off between velocity and accuracy. Differently, the analysis performed over the complex situations revealed that experts had superior ability compared to the other two groups, and that novices performed better than intermediate athletes. The explanation of this result referred to the difference of expertise between intermediates and novices. The data analysis of eye movements recorded in the complex situations revealed that the upper parts of the body, i.e., head, arm and trunk, were the targets where expert athletes mainly addressed their gaze, whereas novices observed more the lower parts. Again, experts had fewer, but longer, fixations on their target than novices and intermediates. Regarding the location of fixations, outcomes appeared unusual because during the standard training sessions, athletes are used to being advised by their coaches to pay attention to the movements of the opponents' lower limbs. The duration of fixations acquires stronger meaning when it is considered along with the meta-analysis of Mann and colleagues (2007): these authors conclude that fixations and accuracy are correlated: the longer the fixation, the more accurate is the visual information that can be extracted. Moreover, duration apart, there was a further important issue the authors discovered: experts appeared to adopt a visual strategy that was called "Pivot": each counterpart's movements were analysed by the observer by anchoring the gaze of the latter over the head of the opponent. In this way, athletes can have a broader perception of the opponent's body and movements. Such a strategy was supported by considering two complementary perspectives at the same time: the first perspective entails the attention shift described by Posner (1980), the second perspective considers psychophysiological aspects. The former assumes that athletes moved their attention while focusing upon a specific area of interest (Nougier et al., 1989; Posner, 1980), whereas the latter argued that the peripheral vision of the athletes serves to identify the relevant stimuli, which can be analysed by foveal vision afterwards (Ripoll et al., 1995). Recent results confirmed the trade-off between accuracy and reaction times observed by Ripoll and colleagues (1995): higher reaction times correlate with deeper information analysis in experts, but not in novices (e.g., Mann and colleagues 2007; Mori et al., 2002; Ottoboni et al., 2015).

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

Initially, the authors did not expect these results; according to their assumption, anxiety would have facilitated the speed of performance at the expense of accuracy (Starkes and Allard, 1983). In the end, the authors explained the findings as a result of the *Processing Efficiency Theory* (Eysenck & Calvo, 1992). This theory argues that athletes maintain a stable performance by increasing their general cognitive effort. Under this light, karate athletes should have kept their performance at a high level by increasing the attentional resources at the cost of mental effort. Under the same stressful conditions, the authors also observed a change in the visual behaviour: the number of fixations increased while the fixations were focused on peripheral body parts, such as arms and fists. The result were said to be related to an increased sensitivity in detecting threatening stimuli (Sarason, 1984), which, in turn, should have both narrowed the central vision (Easterbrook, 1959; Bacon, 1974), and decreased the general attentional control (as later stated by the *Attentional Control Theory* of Eysenck et al., 2007).

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

Differently from the study reported above, which was concentrated with studying attacks and responses, Petri and colleagues (2018) investigated the role of the facial expression on a karate anticipation task. The study arose from what was suggested by both Williams and Elliot, and by Ripoll et al. (1995): expert athletes gaze at the head instead of at other body parts. The authors developed two experiments, one with realistic stimuli and one with a real paradigm. Thus, in this section we report on the experiment with dynamic realistic videos. Ten karate expert athletes participated in the investigation; they had to verbally recognize the type of attack while the face of the attackers was blurred or normal. Participants recognized the attack more accurately while the face was blurred. The fact that, by removing the face of the counterpart, the recognition improved, supports the assumption that facial expressions convey important information affecting sport performance by dragging away participants' attention from important cues.

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

Static pictures

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

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

The taekwondo study (Shi & Lin, 2016) tested whether, beyond the abilities to recognise sport specific patterns of movements such as the round kick, combat sports athletes can also recognise emotional expression better than non-athletes and weightlifters. The authors presented to 13 taekwondo athletes, 14 weightlifters and 14 non-athletes pictures extrapolated from footage of two taekwondo foot attacks, the "Snatch" Olympic weightlift and the emotional facial expressions (e.g. angry and happy). The videos were performed both by a woman and a man, and participants had to recognize as soon as possible the kind of taekwondo kick (frontal or circular), the good outcomes of the weightlift action and the facial emotion (angry or happiness). Taekwondo athletes and weightlifters were better in recognizing actions congruent with their expertise in terms of reaction times for the taekwondo athletes and accuracy for the weightlifters; no difference emerged from the analysis of facial expressions. However, a significant correlation was found in the taekwondo athletes between the accuracy of taekwondo actions and facial expressions. The authors suggested that the facial emotion might play a role in action recognition as observed in the recent study of Petri and colleagues (2018). The experiment provided further evidence supporting the ability to encode movements starting from static pictures (Blakemore & Decety, 2001).

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

In line with the previous two studies, but differentiating for what concerns the focus set upon VEP/ERPs (visual/event-related potentials), Del Percio and colleagues (2007) invited 31 karateka (17 experts and 14 novices) and 15 non-athletes to judge pictures of basketball and karate attacks. The authors aim was at testing the behavioural and electrophysiological superiority of experts over the other two classes of participants. Participants were required to judge the direction of attacks. The task was accomplished while VEP/ERPs were recorded: P1, N1, P2, P3 and N2 amplitudes are granted to correlate, respectively, with cognitive performances as visual-spatial attention (P1; Delpont Dolisi, Suisse, Bodino & Gastaud, 1991), visual-discriminative attention (N1; Di Russo, Taddei, Apnile Spinelli, 2006), control inhibit and preparatory activity (P3; Hamon and Seri, 1989; Polich and Lardon, 1997), and sensory discrimination for the motor response (N2; Renault, Ragot, Lesevre & Remond, 1982).It was assumed by Del Percio and colleagues that this would increase the knowledge regarding specific visual stimuli; however, no differences in judgement accuracy emerged among the groups.

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

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

Another interesting aspect is that athletes have superior performance both with dynamic videos and static pictures. Thus, the athletes are able to perceive movements by observing both body postures and footage (Tessari, Ottoboni, Mazzatenta, Merla, & Nicoletti, 2012; Rosalie & Müller, 2013, 2014). On the other hand, pictures might be unable to fully represent sports' complexity, dynamism and uncertainty of the sport environment where athletes usually play (Abernethy, Burgess-Limerick & Parks, 1994a; Brunswink, 1955 Mann, Williams, Ward & Janelle, 2007; Mann et al., 2007) when compared to video. To conclude, the present series of research suggests two aspects: the first is concerned with the use of video or picture stimuli: each of them can be used in the light of the researcher's demand. For instance, pictures are less complicated to manage than dynamic videos as the synchronization with other devices (e.g. Transcranial Magnetic Stimulation - TMS). The second regards electrophysiological evidences: the results yielded so far do not depict a clear picture about athletes' brain functioning, and further investigations are necessary to better understand combat sport athletes' brain functions.

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

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

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

Rosalie and Müller (2013 & 2014) investigated anticipation abilities in two studies. Moreover, the 2014 study investigated whether such a capability was domain-dependent, i.e., they explored whether athletes can only anticipate the outcomes of the sports they practice, or if the anticipation skill might be extended across other sports. In 2013, the authors required 8 international karate athletes (experts), 8 national karate athletes (intermediates) and 7 novices to perform a real, *in-situ* anticipation task. In order to test anticipatory skills, participants wore goggles designed to occlude the vision of the opponent's attacks at four different times. In particular, the occlusion occurred just after the show of the initial stance position (0 ms), i.e., when just small head movements are performed in preparatory phase; after 50 ms from the beginning of the action, i.e., when the head of the opponent implemented the first preparatory movements, after 100 ms, i.e., when initial movements of attack were performed, or no occlusion, i.e., leaving the athletes to observe the complete action execution. The task required participants to respond by performing a real movement in order to block the attack. In all the cases but one, the experts showed better anticipation skills than the other two groups. The exception was at 0 ms occlusion: in this case experts performed the task significantly better than novices, but similarly with intermediates. Moreover, the latter were superior to novices in three occlusion conditions, i.e. 50 ms, 100 ms and no occlusion. These results confirmed the higher capability of expert athletes to extrapolate information either from very subtle movement cues or from static pictures representing action postures displayed for a very short time (Mori et al., 2002; Ottoboni et al., 2015; Shi and Li, 2016).

In 2014 the same authors, whose work has been just described (Rosalie and Müller, 2014), examined the possibility of transferring the expertise of anticipating the outcomes of a sport that one knows to other, either similar or dissimilar sport domains. This was done in order to understand whether the anticipation processes are principle based, or due to the similarity of the sports tested. Thus, the research was aimed at clarifying what has been so far controversially reported in the literature: i.e., to clarify whether anticipation ability is witnessed across disciplines (Abernethy et al. 2003, Williams & Roca, 2017), or whether the transferability regards only some abilities but not anticipation (Gorman, Abernethy & Farrow, 2011). To achieve this goal, karate athletes (6 experts, 6 semi-experts and 6 novices) carried out anticipation tasks in both taekwondo and Australian football settings. Further, in order to compare the performances recorded in karate athletes, taekwondo athletes (6 experts and 6 semi-experts) and Australian football players (8 experts and 8 semi-experts) were recruited. The authors adopted the same paradigm as Rosalie and Müller (2013) but changing occlusion timing on Australian football actions. In the task involving taekwondo actions, participants had to defend themselves from the attacks, while in the task involving Australian football actions, the participants could decide whether to tackle the opponent or to intercept the ball. The karate athletes' data highlighted the ability to transfer the expertise from the sport athletes to both similar (taekwondo) and dissimilar (Australian football) domains. It emerged, however, that expertise can be transferred more easily across similar contexts (i.e., from karate to taekwondo than from karate to Australian football). These results are in line with the investigation of Williams and Roca (2017) where football players anticipated basketball-related actions more reliably than tennis-related ones.

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

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

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

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

Recently Petri et al. 2017 investigated the anticipation skills through kinematic analysis with a 3D-capture analysis tool which is more accurate than other instruments (e.g., high speed video cameras, for a review of benefits and drawbacks of the different motion capture instruments in sport see van der Kruk & Reijne, 2018). They focused on understanding whether the type of attacks and the distance between the fighters are relevant keys in the anticipation processes. Four expert karate athletes fought one against the other (Piras et al., 2014; Rosalie & Müller, 2013, 2014); the attacking fighters were free to perform one of three possible karate attacks: two punches (reverse and jab punch) and one kick (round kick); the defending fighters had to defend themselves or to counterattack. The results showed that the jab punch was the easiest attack to code and react against. The authors argued that such facilitation is given by implicit and subtle preparatory movements that athletes carried out involuntarily (Mori et al., 2002; Rosalie & Müller, 2013, 2014). Summarizing, the research using real-scenarios, both videos and pictures, confirmed that experts showed better perceptual – cognitive skills than non-experts; the former can encode kinematic movements of the opponent far before the attack releases, as they rely on implicit analyses of subtle cues in the body movements of their opponents.

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

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

An extensive number of investigations examined the perceptual – cognitive skills of combat sport athletes by means of paradigms such as the Posner-like one, GO/NO-GO task, visual perception speed, and choice reaction time tasks (Bianco, Di Russo, Perri & Berchicci, 2017; Bianco, Ferri, Fabiano, Giorgiano, Tavella, Manili et al., 2011; Bianco, Ferri, Fabiano, Scardigno, Tavella, Caccia et al., 2008; Chen, Song, Chou, Wang & Goodbourn, 2017; Cojocariu and Abalase, 2012); Di Russo & Spinelli, 2010; Del Percio, Babiloni, Infarinato, Marzano, Iacoboni, Lizio, 2009; Fontani, Lodi, Felici, Migliorini, & Corradeschi, 2006; Guizani, Tenenbaum, Bouzaouach, Kheder, Feki & Bouaziz, 2006; Kim & Petrakis, 1998; Lesiakowski et al., 2013; Mori et al., 2002; Muiños & Ballesteros, 2013, 2014; Nougier, Ripoll & Stein, 1989; Sanchez-Lopez, Fernandez, Silva-Pereyra, Martinez-Mesa & Di Russo, 2014). These experiments were aimed at understanding the basic cognitive processes of skilled fight sport athletes when compared against less skilled athletes or non-athletes. Moreover, they investigated whether the sport practice could have a positive role on cognitive functions. As hypothesised in the research reported in the previous chapters, researchers tended to assume better stimuli discrimination and faster responses in skilled combat sport athletes than in less skilled ones and non-athletes (Voss et al., 2010).

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

In the second experiment, the same task was presented to *savate* athletes, penta-athletes and archery athletes. Results showed the archery group was the fastest group compared to the others. Moreover, as in the first experiment, participants spent more time to respond to the far than the near stimuli (Nicoletti & Umiltà, 1989). The study on visual spatial speed performed by Kim and Petrakis (1998) involved karateka with different levels of expertise (30 experts, 30 intermediates and 35 novices). The study reports that experts demonstrate a better performance compared with both intermediates and novices, while no differences emerged between less experienced athletes and intermediates. According to the authors, the results were given by the best visuo-spatial processes developed by the expert athletes.

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

Chen and colleagues (2017) presented 38 expert taekwondo athletes, 24 expert karateka and 20 non-athletes with an eye – hand coordination task, a perceptual – processing speed task and an attentional control task (e.g. COVAT task – Covert Orienting of Visual Attention). The COVAT is a task very similar to the task adopted in Del Percio's group (2009) and already described. Chen and colleagues (2017) hypothesised differences among the three groups as they assumed differences among the combat sports. The data analysis partially confirmed the assumption: karateka showed better eye – hand coordination than other two groups; while no differences emerged between the performance of the taekwondo group and non-athletes. The COVAT task reported the perceptual processing speed of karate and taekwondo athletes to be faster than non-athletes, while no differences emerged between the two sport groups. An analysis on attentional control, again, did not show differences among the three groups.

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

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

Athletes' superiority is questioned again in a series of studies investigating visual spatial attention. The results reported by Lesiakowski and colleagues (2013) showed no difference in attentional behaviour between (15) expert boxers and (15) non-athletes; Muiños and Ballesteros (2013, 2014), however, showed that the 16 skilled kung-fu athletes they enrolled were able to detect flash stimuli better than the 15 non-athletes when stimuli were presented peripherally at high frequencies. The same authors (2014) recruited 30 skilled judo athletes, 30 skilled karateka and 30 non-athletes (all young adults) for one of their studies. Participants performed a task where a dot appeared in different positions on the screen. Athletes showed faster reaction times. Moreover,, as well as responding with the fastest reaction times, the karateka also showed better peripheral vision as they were better able to recognize peripheral stimuli than the other groups. The same authors, again, examined 45 old males (age range between 55 – 68 years old), 15 old expert judo athletes, 15 old expert karateka and 15 non-athletes and reported that the karateka and judoka provided faster responses than the non-athletes.

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

Two more studies (Bianco et al., 2017; Di Russo & Spinelli, 2010) adopted a GO/NO-GO paradigm to compare skilled fencers, skilled boxers and control participants both from the behavioural and electrophysiological perspectives. Di Russo and Spinelli (2010) analysed the reaction times, the switch cost (i.e. the difference between NO-GO and GO trials reaction times) and the P1, P2, P3, N1 and N2 waves. The reaction times were similar among the groups, even if fencers reacted significantly faster than non-athletes. However, the switch cost emerged higher for boxers than fencers and non-athletes. The electrophysiological data revealed similar P1 and P2 components among the groups and between the conditions (GO and NO-GO). Differences instead emerged for N2, N1 and P3 components. In particular, fencers demonstrated improved visual attention (N1 waves) and in the NO-GO condition a great inhibition of motor responses (N2 component). In addition to what the colleagues just mentioned, Bianco and colleagues (2017) analysed two components of readiness: the "Bereitschaftspotential" (BP) and the prefrontal Negativity (pN) waves in 13 fencers, 13 boxing athletes and 13 non-athletes (control group). Whereas BP, whose amplitude is associated to faster responses (Oken & Philips, 2009; Sangals, Sommer, & Leuthold, 2002; Shibasaki & Hallet, 2006), showed greater amplitude in both boxing athletes and fencers than in the control group. pN waves, the amplitude of which reveals the amount of attentional resources involved in the task, showed greater amplitude only in fencers. Moreover, the P1, N1, N2 and P3 waves recorded after the stimulus presentation showed strong amplitudes in the group of fencers. With regards to the behaviour results, reaction times were faster in experts than in the control group, while boxing athletes showed less accuracy than others.

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

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

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

Perceptual-cognitive training in laboratory and on field

Despite the high interest showed by coaches, physical trainers and researches about the possibility to increase athletes perceptual – cognitive skills and to transfer them from the lab into field, the number of investigations focusing on such a topic are limited and relegated to the hopes of transferring the skills' enhancements from the labs into practice (Abernethy et al. 2012; Broadbent et al. 2015; Farrow, 2013).

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

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

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

Discussion

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

The evidence we gathered by addressing the keywords reported in the introduction reveals that, in combat sports, the superiority of experts (either sportsmen or lay people; Mann et al., 2007; Voss et al., 2010) does not manifest itself to the degree that was expected. Indeed, the better performance reported in responses to real and simulated stimulations were not consistent with the results achieved using general paradigms. In sport related tasks, instead, experts anticipate the actions of their opponents more efficiently than their less skilled counterparts can (e.g. Milazzo et al., 2016; Mori et al., 2002; Ripoll et al., 1995; Williams & Elliot, 1999). Experts were able to encode the movements of the opponents far before their actions executed (Rosalie & Müller, 2014), and the coding was finalized at planning the most appropriate sport-related action (Ottoboni et al., 2015). Some interesting visual search characteristics arise from these studies too. For example, in order to accomplish visual search tasks, combat experts were observed to adopt either a "Pivot" strategy (Milazzo et al., 2016; Piras et al., 2014; Ripoll et al., 1995; Williams & Elliot, 1999), or "a middle" strategy (Nougier et al., 1989). The former consists of anchoring athletes' gaze upon the zones of the opponents' body that are in the middle, between the head and the relevant body parts used to deliver the attack; whereas the latter consists on focusing attention in visual field areas which are in the middle between two consecutive stimulations. Such strategies provide very important advantages: they help athletes in shifting attention towards the areas of the body that are very interesting for either attacks or event-related visual analysis. Such a habit governs the distribution of visual attention in other sports too. In volleyball and in football, for example, athletes pay more attention in areas of space where the action of their sport typically occur (e.g., in the lower and in the upper visual hemi-field, respectively (Castiello & Umiltà, 1997; for a review see Vater, Williams & Hossner, 2019). However, combat experts are used to exert fewer fixations above the sport-key areas, although they look at them for longer (Mann et al., 2007). From these results the eye-tracking appears to be a very important technique because it is capable of providing very interesting insight on processes of information selection and attention (Ripoll et al., 1995; Williams & Elliot, 1999; Deubel & Schneider, 1996; Panchuck, Vine & Vickers, 2015 for an overview). Nowadays, eye-trackers have become extremely affordable and flexible (e.g. Gibaldi, Vanegas, Bex & Maiello, 2017), as they can be adapted to assess human performance in both real and simulated settings (Schack, Bertollo, Koester Maycock & Essig, 2014), as well as in settings using Virtual or Augmented Reality protocol (Stelling-Konczak, Vlakveld, van Gent, Commandeur, van Wee & Hagenzieker, 2018).

Conversely to what was observed in real and simulated settings, general paradigms (see Chen et al., 2017, Del Percio et al., 2009; Kim & Petrakis, 1998; Nougier, Ripoll & Stein, 1989) produced outcomes which were in line with the results of Voss and colleagues (2010). These results are not so uncommon, indeed, recent finding tried to analyse the non-sport related perceptual – cognitive skills in football referees, but no difference emerged between the groups tested (Spitz et al., 2017). A reason for this might reside in the fact that the real and simulated studies did not use the same paradigm, they differ a lot depending on the adopted stimuli, dependent variables, and/or groups of tested athletes (e.g. small differences in the expertise). This methodological controversy might be solved by what was proposed by Mori and colleagues (2002): the authors controlled the outcomes which athletes achieved in realistic settings using the outcomes achieved in general settings. These differences could be further debated in order to comprehend whether expertise can enhance cognitive functions, or it is just sport related in general; raising the question whether to continue investigations into these kinds of abilities.

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

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

Concerning the athletes' expertise, our literature review reveals that the strategies to sort athletes into expert and less-expert categories are very heterogeneous. Some authors (e.g. Piras et al., 2014) considered people who have been trained for 18 hours overall as being novice athletes. Other authors defined novice athletes as people who had gained two or three years of experience (Del Percio et al., 2007, Ottoboni et al., 2015). On the other hand, expert athletes are labelled as the ones having had more than 8 – 10 years of sport experience (Del Percio et al., 2009; Fontani et al., 2006; Piras et al., 2014), but Mori et al.'s (2002) defined experts as athletes who had 4 – 6 years of experience. It is crystal clear that this heterogeneity must be solved soon. Important indications could come from the ranking adopted in the fighters' leagues (e.g., WKF). Another indication may be the ten years rule (Ericsson, 2006), where experts are identified as having been trained for at least 10000 hours. Furthermore, the definition of intermediate and novice athletes appears more complicated still, because the training level might be confounded by athletes' innate skills. In this light, athletes at the beginning of their career might have a level of performance very similar to intermediates, or on the contrary, athletes with intermediate expertise might have abilities comparable to novices.

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

The last limitation we pointed out regards the methodology disparity. Due to the different experimental designs and stimuli adopted, no investigations replicating previous results emerged from our search. Several tasks examined the attentional processes and the cognitive functions, but they evaluated different aspects of them, e.g., attentional task (Nougier et al., 1989), COVAT (Chen et al., 2017), Posner paradigm (Del Percio et al., (2009), Identical Picture Test (Kim & Petrakis), visual – spatial task (Mūinos & Ballesteros, 2013, 2014). Thus, the overview the research provided is featured by complexity. The real stimuli and simulated scenarios, instead, tried to examine abilities such as anticipation, action recognition, and decision–making (Mori et al., 2002; Ripoll et al., 1995; Rosaline & Muller, 2014; Williams & Elliott, 1999). Often, this research was concerned with temporal occlusion paradigms, but not adopting standardized actions. Moreover, in these studies, the actors whose actions were used to compose the stimuli array should be able to perform the actions in a perfect way (e.g., with no error or personal addendum);however, this is quite improbable due to the intrinsic variability in the execution of the real actions. In discussing this line of research, realistic paradigms attempt to translate 3-D simulated scenes into a 2-D world. Although the reduction of a visual dimension might bias athletes' perception and responses, the use of such settings guarantees more accurate measurement than the studies in real situations (Mann et al. 2007; Williams & Ericsson, 2005; Witte, Emmermacher, Bandow & Masik, 2012).

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

Conclusion

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

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

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

Petri, Bandow, Salb & Witte (2018)	Karate	Study A 10 karateta (5 females) Study B 12 karateka (6 females)	19.5 ± 5.8 20.6 ± 6.4	National and International level	**Study A** Realistic (footages) **Study B** *In-situ*	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.
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	**Simple task** No differences among the groups **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	*In situ*	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	*In situ*	Anticipation task	Fixations	Visual search behaviour: EXP less fixations of longer duration. NOV more fixations

		11 NOV	23.64 ± 1.80)	experience 14 hrs (white belt)				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	16–31; 23.5 ± 7.5	International competitions	*In situ*	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	*In situ*	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	*In situ*	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								
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 **Electrophysiogical 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

		(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 **Electrophysiogical 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** *At rest:* table tennis players were the slowest compared to other groups. Fencers were quicker than boxing athletes. Fencers = tennis players. *After workloads* Faster reaction times for fencers and tennis players. Boxing and table tennis players showed a particular trend.
Kim & Petrakis (1998)	Karate	30 EXP (15 females)	Females: 23.1	Black belt	General paradigm	Identical Picture Test	Accuracy	Expert athletes had better visuo-perceptual abilities compared with intermediates and novices.

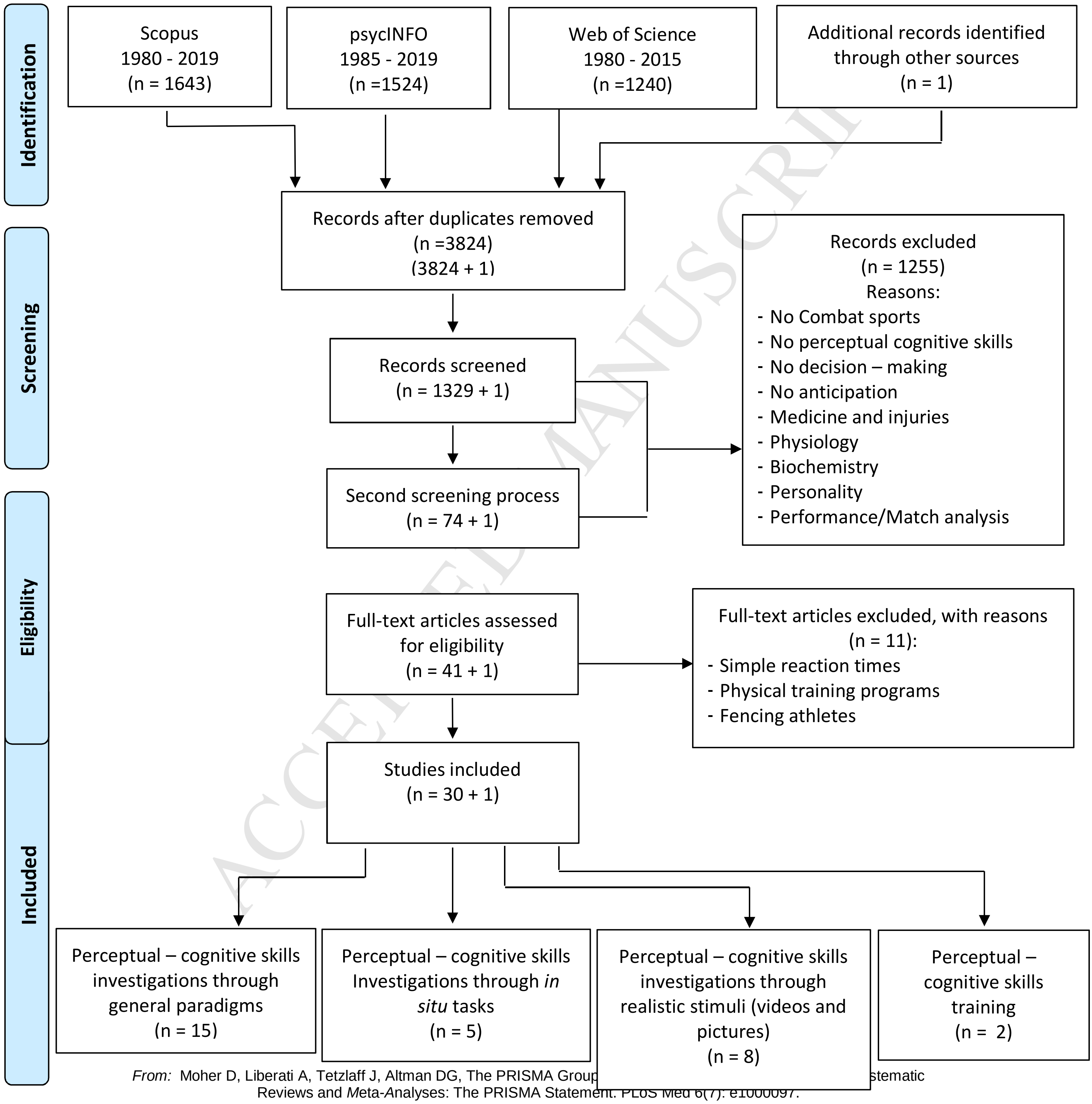
		30 INT (15 female) 35 NOV (15 females)	Males: 22.6	Blue belt White belt				No differences between intermediates and novices were found.
Lesiakowski, Zwierko & Krzepota (2013)	Boxing	15 EXP (5 females) 15 non-boxing athletes	(20.4 ± 5.2) (21.9 ± 1.96)	National team athletes No-experience	General paradigms	Visual – spatial attention task	Reaction times	No-differences between the groups
Muiños & Ballesteros (2014)	Karate Judo	Experiment 1 30 young judokas 30 young karateka 30 young non-athletes Experiment 2 15 old judokas 15 old karateka 15 old non-athletes	21–32 (27.6 ± 3.8) 19–34 (25.3 ± 4.8) 19–28 (23.5 ± 4.8) 60–67 (64.1± 3.6) 55–65 (63.7 ± 3.2) 55–68 (64.7 ± 4.3)	Athletes: International No-experience Old athletes: More than 10 yrs No-experience	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
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 1year 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

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) & *In situ*	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 *in-situ 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.

Percetual – cognitive skills PRISMA Flow Diagram



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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.