Visuospatial Attention and Motor Skills in *Kung-Fu* Athletes

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Abstract

The present study compared the performance of a group of 16 *kung-fu* athletes with that of a control group of 14 non-athletes on a speeded visuospatial task and a hand-tapping motor task. In the visuospatial task, the results showed that athletes were faster than the control participants when stimuli were presented at the periphery of the visual field at a middle and high presentation speed with short inter-stimulus intervals (ISI). Athletes were also significantly faster than non-athlete participants when performing motor actions such as hand-tapping with their dominant hand but groups did not differ with the non-dominant hand. These results support the view that athletes perform some speeded visuospatial and motor tasks faster than non-athletes under certain conditions. The findings suggest that after several years of practice, *kung-fu* athletes develop certain skills that allow them to perform motor speed maneuvers under time pressure conditions.

Key words: Martial arts; Motor abilities; Peripheral vision; Visuospatial attention; *Kung-fu* athletes.

The role of perceptual and motor skills is critical in sports. Martial arts, which involve fast movements, usually impose extreme demands and require practitioners to develop certain skills to avoid attacks coming from various points, including the visual periphery. *Kung-fu* is a Chinese martial art which literally means "martial art" in Chinese. This fast-moving sport uses punches, kicks, jumps, joint manipulation, grappling and also a variety of weapons, but its main features are balance and twisting of the body, flexibility, and the performance of circular movements. The importance of being able to respond to lateral attacks makes it very suitable for the study of peripheral vision.

Peripheral vision has been studied in other sports (e.g., Schorer, Rienhoff, Fischer, & Baker, 2013; Zwierko, 2007; Zwierko, Osinki, Lubinski, Czepita, & Florkiewicz, 2010), but surprisingly, there is a lack of research in *kung-fu*. Given the importance in this sport of paying attention to things happening peripherally and the predisposition to respond to lateral attacks, the study of peripheral perception is an important research endeavor. *Kung-fu* training involves circular movements executed more laterally than in other related martial arts such as karate or taekwondo.

Perceptual and motor abilities in sports have been extensively investigated over the past two decades with mixed results. While some studies have reported significant differences between athletes and non-athletes only when stimuli related to the practiced sport are used (e.g., Memmert, Simons, & Grimme, 2009; Nougier, Azemar, Stein & Ripoll, 1992), other researchers have also reported differences in performance with generic or more simple stimuli not related to the practiced sport (e.g., Arkaru, Çaliskan, & Dane, 2009; Giglia, Brighina, Zangla, Bianco, Chiavetta, Palma, *et al.,* 2011; Mori, Ohtani, & Imanaka, 2002).

In non-athlete participants, task-specific training produces a reduction in reaction time (RT) after being trained to detect stimuli appearing at peripheral and central locations of the visual field. Ando, Kida, and Oda (2004; see also Ciuffreda, 2011) obtained a large effect size for both peripheral (d = 1.46) and central (d = 0.86) locations with practice. Importantly, improvements were still present 3-weeks after training, thus suggesting neuroplasticity. If a short task-specific training improved RT for stimuli presented at peripheral and central visual fields, we reasoned that the continuous practice of the sport would facilitate the rapid detection of generic stimuli appearing at peripheral locations of the visual field.

Several behavioral studies suggest that athletes have better visual skills than non-athletes and that this allows them to process some visual information better. However, other studies indicate that experts do not have better visuospatial abilities than novices but that they are more efficient in certain contexts (Abernethy, Neal, & Koning, 1994; Williams, Davids, Burwitz, &Williams, 1994; Wu, Zeng, Zhang, Wang, Wang, Tan, *et al*., 2013; Zwiero, 2007; Zwierko et al., 2010). For example, Zwierko (2007) found significant differences with a larger effect size (d = 1.064 and d = 1.05) between handball players and sedentary participants in two peripheral vision conditions using simple stimuli. In a more recent study, Zwierko and colleagues (Zwierko *et al*., 2010) also reported a large effect size (d = 0.94) in volleyball players compared with non-expert participants.

Ripoll, Kerlizin, Stein, and Reine (1995) suggested that experts develop more economical and holistic visual search patterns than novices. In their study, the visual strategy differed, with experts making fewer but longer visual fixations, most of them directed to the head, whereas novices made more visual fixations on the arms and fists. In a recent study, Millslagle, Hines, and Smith (2013) also reported a different pattern of fixations between baseball experts and non-experts. This different pattern of fixations supports the view that athletes and non-athletes may differ in visuospatial perception. Taken together, these results encouraged us to explore the visual abilities and motor performance of elite *kung-fu* athletes.

Athletes, especially those engaged in combat sports, execute motor movements under time pressure because they have to respond as quickly as possible to sequences of opponent attacks. These rapid motor maneuvers occur mainly automatically (Kibele, 2006). These “prepared” motor reactions are based on a long learning process. Some of the variables that facilitate the learning of motor skills are repetition (Malouin & Richards, 2010; Melnik, Lersten, & Lockhart, 2009), “motor imagery” or “mental practice”, amount of practice (Post, Fairbrother, & Barros, 2011), and knowledge of results or feedback (Badami, VaezMousavi, Wuif, & Namazizadeh, 2012; Bitter, Hillier, & Civetta, 2011). One issue of great interest is whether athletes are more accurate and faster than non-athletes in other basic motor activities, different from those practiced repetitively during training. In a previous study, Mori, Ohtani, and Imanaka (2002) found significant differences between karate experts and non-athletes in a basic motor task (responding to dots presented rapidly on the computer screen), although the differences were greater in more complex motor tasks involving scenes of karate attacks. Other researchers have reported differences in hemispheric specialization between proficient judo sportsmen and controls. Experts, but not control participants, preferred to perform certain maneuvers with the non-dominant hand (Mikheev, Mohr, Afanasiev, Landis, & Thut, 2002). In lateralized auditory and visual tasks, experts showed greater right hemisphere involvement compared to controls. The authors suggested that lateral preferences are modified during the acquisition of motor skills, probably due to neuroplasticity. For example, performing certain tasks with the non-dominant hand could give judo athletes an advantage in their sport (Abrams & Panaggio, 2012). This different pattern in terms of lateralization encouraged us to explore possible differences between *kung-fu* athletes and non-athletes.

To our knowledge, this is the first study to investigate visuospatial and motor skills in *kung-fu* experts. Although it is important to study visual attention abilities and peripheral vision in all sports, it is especially so in sports such as *kung-fu* that are characterized by a predisposition to respond to lateral attacks. In the present study, we expected to find shorter reaction times in the *kung-fu* group compared to a control group, as well as a different pattern of lateralization in the motor task.

Thus, the aims of the present study were two-fold: (1) to examine whether *kung-fu* athletes were better than non-athletes in visuospatial attention assessed by a speeded visual task, and (2) to investigate differences in laterality between the two groups in a speeded motor task. More specifically, we hypothesized that *kung-fu* athletes would have better visuospatial attention, expressed by shorter reaction times (RTs) than control participants. We also expected that athletes would outperform control participants when the visual stimuli were presented at the periphery of the visual field because of the importance of paying attention to things that happen peripherally in their sport. The second hypothesis was that *kung-fu* experts would show faster motor hand responses than the non-athlete group as expressed by a larger number of taps.

Method

Participants

Thirty male volunteers participated in the present study. The athlete group was composed of 16 participants (mean age 30.69 years; SD = 5.73; range 20-39). All were internationally competitive, high-level professional *kung-fu* practitioners with a similar level of expertise. All were black belt with at least 10 years of sport´s practice. The mean number of hours that these athletes dedicated to practice *kung-fu* was 13 hours per week. The control group comprised 14 participants without experience in combat sports (mean age 30.28 years; SD = 4.33; range 22-35). Participants in the athlete group came from various martial arts schools. The two groups were matched for age and sociocultural level assessed with the Goldthorpe- Hope scale (Goldthorpe & Hope, 1974). None of the participants were suffering from any general health problems, refractive eye disorders or low visual acuity. All participants gave informed consent for participation in the study, which was approved by the Ethical Review Board of the Universidad Nacional de Educación a Distancia. The experiments were carried out in accordance with the World Medical Association Helsinki Declaration as revised in October 2008.

Measures

To assess visuospatial attention and hand-tapping motor skills, participants performed a computerized task, the Visual Field Attention task to assess visual attention depending on different eccentricities, and the Motor Speed task to assess motor speed responses with their dominant and non-dominant hands (Brainmetric Software, 2004), using a Fujitsu Siemens laptop with a 15.4 inch screen.

Procedures

Participants were tested in a quiet room with a luminance of 85 cd/m2 and a temperature of 22º C, and the noise level was kept between 5 and 13 decibels. First, they performed the Visual Field Attention task followed by the Motor Speed task.

In the visuospatial task, participants were presented with a fixation dot that appeared at the center of the computer screen while another dot appeared and disappeared at random locations within the visual field at three inter-stimulus intervals

(ISIs). The task consisted of pressing the left mouse button as quickly and accurately as possible when the stimulus appeared. To avoid anticipation, ISIs were randomized. The computer recorded automatically the reaction times (RTs) and the number of errors corresponding to each quadrant of the visual field (upper left and right, lower left and right quadrants) as well as to central and peripheral areas. Participants performed the task with four different randomized eccentricities: 0.9^{o}, 2.5^{o}, 9.5^{o} and 11^{o} and three velocity conditions: low (1500 ms), medium (800 ms) and high (400 ms). Participants performed a total of 150 trials, 50 in each of the three ISI conditions.

The Motor Speed task was used to assess tapping speed. The task consisted of a total of 20 trials (10 with each hand lasting 10 seconds each). Participants tapped repeatedly and as quickly as possible on the space bar of the computer keyboard using the index finger of their dominant and non-dominant hands. All participants were right-handed. The tapping finger was alternated, starting with the dominant hand and then with the non-dominant hand. The computer recorded the number of taps to calculate the average tapping speed with each hand as well as the time interval between taps (in milliseconds). The program also calculated the consistency and rhythm of tapping.

Experimental design

Visual Field Attention task. Data were analyzed using a 2 Group (athletes, non-athletes) x 3 Speed (inter-trial duration: 1500 ms, 800 ms, 400 ms) x 4 Stimulus location (left, right, center, periphery) mixed factorial design with repeated measures in the last two factors.

Motor task. The design was a 2 Group (athletes, non-athletes) x 2 Hand (dominant, non-dominant). Group was the between-subjects factor with hand as repeated measures.

Results

The results corresponding to performance on the visual and motor tasks were analyzed separately.

Visual Field Attention task

Latencies in milliseconds (ms) corresponding to correct responses were the main dependent variable. The average RT was 479 (SD = 41) for athletes and 504 ms (SD = 35) for non-athletes. Errors were also recorded, although the mean percentage did not exceed 1%. Incorrect trials were not included in the data analysis. Table 1 shows the mean performance of the two groups in the experimental conditions.

Insert Table 1 about here

A three-factor mixed ANOVA was conducted on latency with group as the between-subjects variable and speed and location as the within-subjects variables. The Geisser-Greenhouse correction for nonsphericity was applied, where necessary, and is indicated by adjusted degrees of freedom. The results from the 2x3x4 (Group x Speed x Location) ANOVA showed that the main effect of group was statistically significant

[F(1,28) = 4.67, MSe = 0.001, p = 0.039, η^2 = 0.143]. *Kung-fu* athletes were faster (479 ms) than non-athletes (504 ms). The main effects of stimulus location [F(2.34, 65.52) = 13.44; MSe = .001, p < .001, η^2 = 0.32] and speed of presentation [F(1.77, 49.59) = 56.71; MSe = 0.001, p < .001, η^2 = 0.67] were also statistically significant, showing that the location of the stimuli on the visual field and the inter-trial duration of the stimulus affected the results. The stimulus location by group interaction was also significant [F(2.34, 65.52) = 12.25; p < .001, η^2 = 0.304], showing that athletes performed the task faster than non-athletes depending on the location of the stimulus. Simple effects analyses (Keppel, 1991) revealed that *kung-fu* athletes were significantly faster than controls only when stimuli appeared at peripheral locations (p < 0.001). Simple effects at the other locations were not statistically significant, indicating that both groups were similar in speed. The two-way speed of presentation x group interaction was also significant [F(1.77, 49.59) = 3.58; p < .05; η^2 = 0.11. Simple effects analyses revealed that athletes were faster than controls at intermediate (p = 0.036) and short speeds (p = 0.004), suggesting that the differences between *kung-fu* athletes and sedentary participants become greater as stimulus presentation speed increases. At low speed, differences were not significant, indicating that athletes did not differ from non-athletes in this condition. Finally, the three-way group x location x speed interaction was marginally significant [F(3.4, 95.22) = 2.16, p =.08; η^2 = 0.07], suggesting that athletes performed the task faster than controls when the stimulus was presented peripherally at intermediate ($p < 0.001$) and fast speeds ($p < 0.001$), but that the two groups did not differ in other conditions.

Figure 1 shows latencies from the visuospatial task corresponding to the peripheral conditions as a function of presentation speed.

Insert Figure 1 about here

Taken together, these results indicate that the athletes performed better than controls when the stimuli were presented at the periphery of the visual field at fast speeds.

Motor task

The mean number of taps was 72.63 (SD = 13.57) for athletes and 63.62 (SD = 7.09) for non-experts. Figure 2 shows the mean latencies corresponding to the tapping response as a function of group and tapping hand (dominant and non-dominant hands).

Insert Figure 2 about here

The 2x2 (Group x Dominance) mixed factorial ANOVA showed that the main effect of group was statistically significant [$F(1,28) = 5.43$; $MSe = 606.77$, $p = .027$, $\eta^2 = 0.16$], suggesting that athletes were faster in key pressing than non-athletes. The main effect of dominance was also significant [$F(1,28) = 16.37$; $p < .001$, $\eta^2 = 0.37$], showing that both groups were faster with their dominant hand. Importantly, the group x dominance interaction was also significant [$F(1,28) = 7.48$; $MSe = 167.36$, $p = .011$, $\eta^2 = 0.21$], indicating that athletes performed a significantly greater number of key presses (and were therefore faster) than non-athletes when the task was performed with the dominant hand ($p = 0.005$); in other words, *kung-fu* athletes showed greater laterality than control participants.

Discussion

The aim of the present study was to compare the performance of a group of *kung-fu* athletes with that of a control group of non-athletes on a visuospatial task and a motor hand-tapping task. This study yielded two main results. First, athletes were faster on the visuospatial task than non-athletes when the visual stimuli were presented at the periphery of the visual field at intermediate and fast speeds but not when they were presented slowly at other visual regions. Secondly, *kung-fu* athletes were significantly faster at hand-tapping than non-athletes, but only with their dominant hand.

Martial arts practitioners, like other athletes, execute sequences of movements under time pressure. These motor reactions occur mainly automatically due to extended daily practice, suggesting that visual skills related to the sport may be related to this learning process. Our findings are consistent with those of Zwierko (2007), Zwierko *et al*. (2010) and Mori *et al.* (2002) who observed significant differences between athletes and non-athletes in some basic perceptual abilities with large effect sizes. In our visuospatial task, athletes were significantly faster when the stimuli were presented peripherally, especially under intermediate and fast presentation conditions. This difference in response time between groups in the peripheral condition could be due to the phenomenon described by Kibele (2006), whereby sportsmen develop fast maneuvers automatically after years of practice, that is, “prepared” motor reactions based on a learning process. Martial arts (especially *kung-fu*) are based on reacting very quickly to the opponent’s attacks, and it is very common that these attacks start at the periphery of the visual field. It is perhaps for that reason that *kung-fu* athletes are more skilled in the perception of motion occurring at the periphery of the visual field. In our study, we also found that athletes were better when the visual stimuli appeared faster at peripheral locations. When the speed of presentation was slower, differences between athletes and non-athletes were only marginal. The better performance of the *kung-fu* experts under the peripheral condition when the stimuli were presented at a fast speed could be explained by the fact that athletes dedicate great effort to repeat maneuvers at a high speed. So, after years of practice, they developed the ability to detect and respond rapidly to fast moving stimuli (e.g., repelling the attack of an opponent). The fact that the difference between the two groups at low speeds was only marginal could be due to a floor effect.

Regarding the motor task, our results also revealed that the *kung-fu* athletes were faster than the non-athlete participants, but only with their dominant hand. This result does not agree with the findings of previous studies conducted with judo experts (e.g. Abrams & Panaggio, 2012; Mikheev, Mohr, Afanasiev, Landis, & Thut, 2002). For example, Mikheev *et al.* (2002) reported that judo experts showed a greater preference to use their non-dominant hand in certain circumstances than non-judo practitioners.

The authors argued that after an extended period of time practicing certain movements, judo experts develop a different pattern of hemispheric lateralization. If this were the case with our *kung-fu* experts, we would have observed greater differences specifically in the non-dominant hand. In fact, our results were just the opposite. *Kung-fu* athletes outperformed non-experts with their dominant hand with a large effect size ($\eta^2 = 0.2$). This discrepancy may be explained by the fact that judo is primarily based on the opponent's grabs, whereas *kung-fu* is based on discrete punches. Judo athletes use the non-dominant hand to a greater extent to perform certain grabs, whereas in *kung-fu* and other related sports (e.g., karate, taekwondo), athletes have more freedom to choose the hand used in the attack. Due to more intense use of their dominant hand, *kung-fu* athletes do not develop sufficient motor skills with the non-dominant hand (as judo athletes do), and therefore they remain more lateralized.

In sum, the current findings indicate that *kung-fu* athletes perform some visual and motor tasks faster than non-athletes under certain conditions. *Kung-fu* athletes were faster than non-athlete participants, but only when the stimuli appeared at the periphery of the visual field at a high presentation speed with short inter-stimulus intervals. Athletes were also significantly faster than non-athletes when the motor actions were performed with their dominant hand. Athletes and non-athletes did not differ when the motor action was performed with the non-dominant hand. These results suggest that *kung-fu* athletes perform some speeded visuospatial and motor tasks faster than non-athletes but only under certain conditions. The present results suggest that practice helps athletes develop certain skills that allow them to perform motor maneuvers under time pressure conditions.

Further research is needed to investigate in greater depth the type of perceptual and motor differences between experts and non-experts in *kung-fu* and other martial arts.

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Figure Captions

Figure 1. Mean reaction times (in ms) for athletes and non-athletes in the peripheral condition of the visual field attention task, as a function of presentation speed (low, intermediate and rapid). Bars correspond to the standard errors of the mean.

Figure 2. Mean performance for the dominant and non-dominant hands for athletes and non-athletes in the motor task. Bars indicate the standard errors of the mean.

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