Reaction times and anticipatory skills of karate athletes

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Abstract

Two experiments were conducted to investigate the reaction times (RTs) and anticipation of karate athletes. In Experiment 1, choice RTs and simple RTs were measured with two types of stimuli. One was videotaped scenes of opponent’s offensive actions, which simulated the athletes’ view in real situations, and the other was static filled circles, or dots. In the choice RT task, participants were required to indicate as soon as possible whether the offensive actions would be aimed at the upper or middle level of their body, or the dot was presented either at a higher or a lower position. In the simple RT task, they were required to respond as soon as possible when the offensive action started from a static display of the opponent’s ready stance, or a dot appeared on the display. The results showed significant differences between the karate athletes and the novices in the choice RT task, the difference being more marked for the video stimuli than for the dot stimuli. There was no significant difference in simple RT between the two groups of participants, for either type of stimuli. In Experiment 2, the proportions of correct responses (PCRs) were measured for video stimuli which were cut off at the seventh frame from the onset of the opponent’s offensive action. The athletes yielded significantly higher PCRs than the novices. Collectively the results of the two experiments demonstrate the superior anticipatory skills of karate athletes regarding the target area of an opponent’s attack (Scott, Williams, & Davids, Studies in perception and action II: Posters presented at the VIIth International conference on Event Perception and Action, Erlbaum, Hillsdale, NJ, 1993, p. 217; Williams & Elliot, Journal of Sport & Exercise Psychology 21 (1999) 362), together with their advantage over novices in non-specific sensory functions (e.g., vertical discrimination). © 2002 Elsevier Science B.V. All rights reserved.

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1. Introduction

Successful performance in sport requires not only efficient execution of motor behavior but also a high level of perceptual ability. Competitive high-level sports are characterized by severe spatial and temporal constraints imposed on the performer by regulations and the opponents (Williams, Davids, & Williams, 1999). Under such constraints, a player’s ability to quickly and accurately perceive relevant information will facilitate decision making and allow more time for preparation and organization of motor behavior (Houlston & Lowes, 1993; Ripoll, 1991). In sport science, two types of perceptual abilities have been considered relevant to the player’s successful performance. One is primitive, basic sensory functions which are not specific to particular types of sport expertise. Such basic sensory functions have been assessed by optometric measurements (static and dynamic visual acuity, field of view, stereopsis etc.) and simplistic laboratory tasks using generic stimuli (e.g., simple RT task to a flash of light). The majority of results obtained from optometric measurements are equivocal, showing no systematic difference between expert and novice players (Hazel, 1995; Williams et al., 1999; Wood & Abernethy, 1997). There is also a diversity of findings from studies using simplistic laboratory tasks. For example, some studies showed faster simple RTs for experts than novice players (Kioumourtzoglou, Kourtessis, Michalopoulou, & Derri, 1998; Knapp, 1961), but others found little difference due to level of expertise (McLeod, 1987; Slater-Hammel & Stumpner, 1950). A few studies have reported that athletes performed faster than novices in choice RT tasks to generic stimuli, although the differences were generally small (Nougier, Azemar, & Stein, 1992; Whiting & Hutt, 1972).

The other type of perceptual processing is sport-specific perceptual skills. Research has demonstrated that expert sport players are superior to novices in perceptual skills, such as detecting the presence of a ball in briefly presented sport scenes (Allard & Starkes, 1980; Starkes, 1987); making efficient search for relevant, informative parts of the opponent’s body and fields (Abernethy & Russell, 1987; Goulet, Bard, & Fleury, 1989; Ripoll, Kerlirzin, Stein, & Reine, 1995; Williams, Davids, Burwitz, & Williams, 1994); anticipating the ball direction and the opponent’s action from advance information (Abernethy, 1990; Jones & Miles, 1978; Paull & Glenncross, 1997; Williams & Davids, 1998); recalling and recognizing structured scenes of game and play (Allard, Graham, & Paarsalu, 1980; Garland & Barry, 1991; Williams & Davids, 1995). The expert advantage in perceptual skills has been typically investigated by sport-specific realistic stimuli and tasks (e.g., judging future actions in filmed sequences of real play).
Karate is a good example of a competitive sport with high levels of temporal and spatial constraints which require fast reactions. In sparring ("kumite") and matches of karate, two athletes face each other within a 2-m distance, making offensive attacks against each other. The exceptional speed and power of offensive strikes demonstrated by expert karate athletes is well documented (e.g., Cavanagh & Landa, 1976; Kato, 1958; Vos & Binkhorst, 1966; Wilk, McNair, & Feld, 1983). The need to offend and defend against the opponents should lead karate athletes to develop their perceptual abilities, i.e. karate-specific perceptual skills and/or non-specific basic sensory functions, to make fast reactions. Research on this topic is scarce, and the results are mixed. A few studies have used simplistic stimuli and tasks to assess the possible advantage of karate athletes in basic sensory functions. Rasch and Pierson (1963) had karate athletes and amateur wrestlers respond to a light stimulus by pushing a button, and found no difference in RT between them. In contrast, Layton (1993), citing his own study (Layton, 1991), reported that RTs for hitting a punch bag in response to a sound stimulus were faster for karate athletes of advanced grade (black belts) than for those of lower grades, although the RTs of the advanced athletes did not differ in proportion to their grades. Kim and Petrakis (1998) administered the Identical Picture Test, a time-constrained multiple-item test of perceptual judgments, to three groups of karate athletes, and found significantly higher scores (that is, faster judgment for each test item) for the black-belt group than for the lower-level groups.

A couple of studies by Williams and his colleagues have used more realistic stimuli and tasks to examine expertise anticipation of karate athletes, which is one important aspect of perceptual skill (Scott, Williams, & Davids, 1993; Williams & Elliott, 1999). In both studies, the stimuli were dynamic film displays of karate athletes performing offensive attacks against the viewer. The film was presented on a large screen to give a real-size view of the performing athletes. The participant’s task was a choice RT task, where the participants had to respond differently, as soon and accurately as possible, to the attacking positions. The response was made either by verbally indicating the attacking limb (left or right, arm or foot), or making defensive actions as if to avoid the attack. For the latter response mode, the participant’s actions were videotaped during the experiment and later analyzed to determine RTs (times taken until the initiation of defensive actions) and response accuracy (for more detail, see Williams & Elliott, 1999). In either mode, anticipating the attacking position from an early part of the video sequence would lead to faster RTs and/or higher accuracy. Scott et al. (1993) found that karate athletes showed faster RTs than novices for both verbal and action response modes, while the athletes showed higher accuracy only with the action mode. In contrast, Williams and Elliott (1999) showed, in a similar experiment using the action response mode, that the expert karate athletes were no faster than the novices, while the athletes were more accurate than the novices.

In the literature so far reviewed, there appears to be no coherent picture concerning the advantage of expert karate athletes in RT tasks. That is, it is not yet clear
whether they are faster than novices in simplistic settings, possibly due to enhanced sensory functions, and/or they are faster in realistic stimuli and tasks, based on their superior anticipation of the opponent’s attack. Moreover, the differences in participant groups (i.e. level of expertise) and methodologies used make it difficult to relate the previous studies to each other and to draw unified conclusions from their results. The present study was designed to obtain a better understanding of the expertise advantage of karate athletes. For this purpose, we followed a so-called multi-task approach (Williams et al., 1999), in which the performances of expert and novice players are examined across multiple types of tasks and stimuli. The multi-task approach has been proved quite useful to reveal expert superiority in various motor and perceptual abilities, the latter including basic sensory functions and perceptual skills (e.g., Helsen & Starkes, 1999; Reilly, Williams, Nevill, & Franks, 2000; Starkes, 1987). In the first experiment of the present study, we measured RTs from the same group of expert athletes and novices, using two types of stimuli, realistic and simplistic, and two types of response tasks, choice RT and simple RT. The realistic stimuli were dynamic displays of karate athletes performing offensive actions against the viewer (see Figs. 1 and 2), similar to those used in the studies by Scott et al. (1993) and Williams and Elliott (1999). The target positions of the offensive actions were either the upper (‘joh-dan’) or middle (‘chu-dan’) level of the opponent (viewer), as usually defined in the classification of karate techniques in terms of their locations (Egami, 1976). The simplistic stimuli were presentations of a single dot at either an upper or lower location in the stimulus display (see Section 2.1 for more details). In the choice RT task, the participants were required to indicate as soon and as accurately as possible the target location of the attack, or the presentation location of the dot. In the simple RT task, the participants responded as soon as possible when the video stimulus started to move from a static display, or when the dot appeared on the monitor. These methodologies allow us to clarify whether expert karate athletes perform better than novices only when both the stimulus and the task are realistic (i.e., video-stimulus choice-RT task), based on the experts’ superior anticipation, or whether their advantage also exists when the stimulus and/or the task are simplistic (i.e., dot- and video-stimulus simple RT tasks and dot-stimulus choice RT task), because of their high-level basic functions.

In the second experiment, we attempted to examine anticipation of the karate athletes in a paradigm other than an RT task. In karate, as well as in other sports, expert–novice differences exist in perceptual skills other than anticipation, such as motor recall (Hodge & Deakin, 1998) and visual search strategy (Williams & Elliott, 1999). There are also differences in decision making. For example, Chamberlain and Coelho (1993) suggested that in sport-specific situations, novices might be less confident than experts and require a longer time for making decisions. This suggests that the RT task in the first experiment may include a possible advantage of the karate athletes in decision making, in addition to their superior anticipatory skill. To evaluate this possibility, we used a temporal occlusion method, where the participants were given unlimited time to judge as accurately as possible the target positions of the attacks which were occluded before their completion. The method
has been applied successfully to identify anticipatory skills in other sports (e.g., Abernethy, 1990; Abernethy & Russell, 1987; Jones & Miles, 1978). If the results
of this experiment corroborate the RT data of the first experiment, showing a higher accuracy of judgments by the athletes, this would constitute strong evidence that
the karate athletes are superior to the novices in anticipatory skills regarding the attack.

2. Experiment 1

2.1. Method

2.1.1. Participants

Six collegiate karate athletes (mean age of 21 in the range of 19–22) and seven novices (mean age of 28 in the range of 21–43), all males and right handed, participated in this experiment. Four of the athletes had 4–6 yrs of experience of karate training, all with black belts (one of them was awarded black belt just after this study), and the other two had about 1 yr of experience. The novices, including the first and the second authors (ages 39 and 43, respectively), had no experience of karate training but possessed basic knowledge of karate (e.g., names and levels of offensive techniques). Except for the two authors, the novices as well as the athletes were students of Kyoto Institute of Technology.

Prior to the study, the purpose and procedures were explained to the participants, and their informed consents were obtained. All participants had normal or corrected-to-normal acuity and color vision, and they reported no difficulty with the stimuli used in the present study.

2.1.2. Apparatus and stimuli

All stimuli were presented on a high-resolution color monitor (SONY Multiscan GDM-17SE2T), with a screen size of 31 × 23 cm, controlled by a personal computer (COMPAQ DeskPro 5100) with a color graphic system (Cambridge Research Systems VSG2/3), which also controlled the experimental timing, RT measurement and recording from a custom-made response box.

For the video stimuli, offensive actions of three karate athletes with black belts were recorded by a digital video camera (SONY DCR-TRV10). The recording took place in a karate-exercise gymnasium, where the video camera was positioned at the height of 1.7 m and approximately 2 m away from the athlete’s initial position. This camera position simulated the eye level and viewing distance of karate athletes in real sparring situations, so that the video-recorded pictures would replicate actual scenes of the offensive actions against the viewer (Scott et al., 1993; Williams & Elliott, 1999). In recording, the three athletes performed separately. Facing the camera, the athletes first took a ready stance, then executed the offensive action against a virtual opponent standing at the camera position. They demonstrated thrusting punches and kicks several times, from both left and right sides, each action being aimed either at the upper or the middle level. From the recording of their performance, 50 actions (half of them aimed at the upper level, the other half at the middle level) were chosen as the stimuli to be presented in the experiment.
Each stimulus was edited in a form of successive pictures, or frames, and presented at 33 ms per frame on the monitor. The viewing distance of the screen was 26 cm so that the vertical size of the athlete on the screen subtended approximately 19–22 cm, or a visual angle of 40–45°, which matched the real perspective of an athlete standing 2 m away (see above). Figs. 1 and 2 show examples of the frame-edited stimuli. For all the stimuli, the first frame presented the athlete in a ready stance at the initial position. Note that the number of frames taken by the complete action differed among the offensive techniques as well as among the three performing athletes. For the stimuli used here, the numbers ranged from 13 to 20 frames which corresponded to stimulus durations of 430–660 ms. They showed no systematic difference between the actions aimed at the upper level and at the middle level.

For the dot stimuli, a black filled circle (1.5 cm in diameter) was presented on a white background. In the choice RT task, the circle was presented at either, approximately, 7 cm above or below the center of the screen. The size and location of the circles were determined in a preliminary study to ensure clear visibility and discriminability in vertical location. In the simple RT task, the circle was always presented at the center of the screen.

2.1.3. Procedure

The experiment was conducted in a dark booth, where the participants were seated with their head fixed on a chin rest while viewing the CRT screen binocularly. There were four conditions, two stimulus types (video and dot) × 2 RT tasks (choice and simple). In the video-stimulus choice-RT condition, each trial started with 1-s presentation of a fixation point at the center of the screen, followed by 1-s presentation of the first frame of a stimulus, showing a static display of the athlete’s ready stance. Then the action started with successive presentations of the frames (beginning from the first frame) at the rate of 33 ms/frame. The participants were asked to decide, as soon and accurately as possible, whether the offensive action in the stimulus would come to the upper or the middle level of their body. The response was made on a response box, pressing one key by a finger of the right hand for the upper level and the other key by a finger of the left hand for the middle level (cf., Scott et al., 1993; Williams & Elliott, 1999). RTs were measured from the onset of the second frame to the key press. The stimulus presentation was terminated by the key press and replaced with a blank screen. There were five experimental sessions of 50 trials each, with the 50 different stimuli presented once in each session in a random order. For each participant, sessions with less than 90% correct responses were discarded and replaced with new sessions. As a result, four of the athletes group and three of the novice group had to perform one or two extra sessions.

In the video-stimulus simple-RT condition, the stimulus presentation was identical to that of the choice-RT condition, except that the duration of the static ready-stance display varied randomly from 1 to 3 s. This served as a random foreperiod as
typically used in simple RT tasks (Luce, 1986). The participant’s task was to press a key as soon as any change occurred in the static display (by successive frame presentations). As in the choice RT condition, RTs were measured from the onset of the second frame to the key press, which terminated the stimulus presentation. The key press was made by either the left or right hand, in an approximately equal number of trials within a session. There were two sessions of 50 trials each, with random presentations of the 50 stimuli in each session.

In the dot-stimulus choice-RT condition, each trial started with an 1-s blank interval of white background, after which the dot was presented for 33 ms at either an upper or a lower location on the screen, followed by a blank white background. The location of the dot was chosen randomly across trials with equal probability. The participants were asked to report the location as soon and accurately as possible, by pressing one key with the right hand for the upper location or the other key with the left hand for the lower location. RTs were measured from the onset of the dot presentation to the key press. There were two sessions of 125 trials each. In the dot-stimulus simple-RT condition, the duration of the blank interval varied from 1 to 3 s randomly across trials, after which the dot was presented for 33 ms at the center of the screen, followed by a blank screen. The participant’s task was to press a key as soon as the dot was presented. This condition was employed in one session of 100 trials. As in the video simple-RT condition, either the left or right hand was used for the key press, in an approximately equal number of trials per session.

All participants, athletes and novices, completed the four conditions over three or four days depending on their schedule and available time each day. They were given rest periods, as long as they wished, between successive sessions within a day. The order of the conditions was randomized across participants in each group. Before each condition, the participants were given explanations concerning the nature of the task and practice trials until they were familiarized with the task.

2.2. Results

For the choice RT tasks, only RTs for correct responses were used for subsequent analyses (more than 90% of total trials for each participant). They were pooled across sessions and stimulus locations, and averaged for each participant. For the simple RT tasks, all RTs were pooled and averaged for each participant. No outlier exclusion was performed on either choice or simple RT data (Miller, 1988, 1991). Fig. 3 shows the mean RTs of the athlete \( (n = 6) \) and the novice \( (n = 7) \) groups, separately for the four conditions. As can be readily seen in the figure, the mean RTs differed by groups, stimulus types, and RT tasks. The most notable is the very slow RTs of the video-stimulus choice-RT condition; they are more than twice as slow as RTs of any other condition. The second slowest is the dot-stimulus choice-RT
condition. On visual inspection there appears to be no difference between the two simple-RT conditions. For all the conditions, the mean RTs were faster for the athlete group than for the novice group.

A 2 (Group: athlete, novice) × 2 (Stimulus: video, dot) × 2 (Task: choice, simple) ANOVA on the RT data showed that all main effects and interactions were significant: Group, $F(1,11) = 19.01$, Stimulus, $F(1,11) = 1869.08$, Task, $F(1,11) = 1670.62$, Group × Stimulus, $F(1,11) = 34.42$, Group × Task, $F(1,11) = 25.23$, Stimulus × Task, $F(1,11) = 1538.71$, Group × Stimulus × Task, $F(1,11) = 18.13$, all $p < 0.01$. Subsequent analyses of simple main effects, interactions, and simple main effects (following the significant simple interactions) were performed with $F$ tests. For both groups, the choice RTs were significantly slower than the simple RTs in the two stimulus conditions (for the athlete group, $F(1,22) = 1244.60$ in the video and $F(1,22) = 15.59$ in the dot condition, both $p < 0.01$; for the novice group, $F(1,22) = 1988.23$ in the video and $F(1,22) = 31.68$ in the dot condition, both $p < 0.01$). For both groups, the choice RTs were slower in the video than in the dot condition ($F(1,22) = 1297.57$ for the athlete and $F(1,22) = 2118.48$ for the novice group, both $p < 0.01$), but there was no difference in simple RT ($F(1,22) = 1.12$ for the athlete and $F(1,22) = 0.01$ for the novice group). The choice RTs were faster for the athlete group than for the novice group in the video ($F(1,44) = 77.10$, $p < 0.01$) and the dot ($F(1,44) = 5.14$, $p < 0.05$).
conditions, but the simple RTs did not differ between the two groups for either stimulus condition ($F(1,44) = 2.58$ and $0.95$ in the video and the dot condition, respectively).

In the choice RT conditions, proportions of correct responses (PCRs) for either type of stimulus were higher than 90% for each participant, and mean PCRs were identical for the two participant groups: both groups yielded 94.7% for the video stimuli and nearly 100% for the dot stimuli (with one error in 100 trials for a few participants). The lack of difference in PCR between the two groups and the higher PCRs of both groups for the dot stimuli (with the faster RTs) than for the video stimuli clearly indicate the absence of contamination of speed-accuracy trade-off in the choice RT data.

We conducted two additional analyses on the RT data. First, we examined possible learning effects on the choice RTs for the video stimuli. An inspection of individual data showed that the choice RTs tended to be faster for later sessions. Since the participants responded to the same set of 50 stimuli over five sessions, they may have learned the task and improved their performance as the session proceeded. This possibility was confirmed by a 2 (Group: athlete, novice) × 5 (Session: 1–5) ANOVA, which showed significant main effects of Group, $F(1,11) = 52.82$, and Session, $F(4,44) = 18.19$, both $p < 0.01$, but no interaction between them, $F(4,44) = 0.59$. The lack of interaction indicates that the learning effects were not different between the two groups. Second, we examined differences due to the hands used for key pressing. Because the participants were all right-handed and used their right hands to respond to the upper location throughout the choice RT tasks, the RT data may have been contaminated by possible advantages of right-hand key presses and differences in the advantage between the athletes and the novices. We confined our analysis to RTs to the dot stimuli (the video stimuli varied in number of frames and possibly viewing time necessary for the correct decision, which made it difficult to determine true differences, if any, due to the responding hands). In the choice RT task, the mean RTs of the left and the right hand were, respectively, 273 and 272 ms for the athletes, and 302 and 296 ms for the novices. A 2 (Group: athlete, novice) × 2 (Hand: left, right) ANOVA showed a significant main effect of Group, $F(1,11) = 7.36$, $p < 0.05$, but neither main effect of Hand, $F(1,11) = 0.61$, nor Hand–Group interaction, $F(1,11) = 0.37$, was significant. In contrast, both groups showed slight but significant right-hand advantages in the simple RT task, where the two hands were used equally often to press a key in response to a centrally presented dot. The mean RTs of the left and the right hand were, respectively, 241 and 231 ms for the athlete group, and 252 and 242 ms for the novice group. An ANOVA showed a significant main effect of Hand, $F(1,11) = 15.56$, $p < 0.01$, but no main effect of Group, $F(1,11) = 1.05$, or Hand–Group interaction, $F(1,11) = 0.02$. For both groups, the $t$ test showed significant differences between the two hands, $t(5) = 3.04$ for the athlete and $t(6) = 2.03$ for the novice group, both $p < 0.05$. Therefore, the choice RT data of both groups may have been contaminated by right-hand advantages of about 10 ms, indicated by their simple RTs, although the conclusions due to their differences in choice RT are not subject to the right-hand advantage, which did not differ between the two groups.
2.3. Discussion

Despite the relatively small number of participants in the athlete and the novice groups, the results are clear. The superiority of the athletes was evident in the video-stimulus choice-RT condition. The athletes were faster but no more accurate than the novices, consistent with the results of Scott et al. (1993) with the verbal action mode. The approximately 100-ms advantage of the athletes is ascribed to their superior anticipation of the opponent’s attacking position. In the video stimuli used here, the opponent’s attack was completed in 430–660 ms from the start of the motion (13–20 frames at 33 ms/frame), while the athletes’ mean RT to those stimuli was 552 ms, which must have included an irreducible latency, approximately 200 ms, for neural transmission and response execution (McLeod, 1987; Williams et al., 1994). Subtraction of 200 ms from the athletes’ mean RT indicates that their decisions were made before the offensive actions were completed in the video stimuli. The same argument applies to the novices. Their mean choice RT to the video stimuli was 657 ms, and the time delay for the response would be the same as that taken for the athletes (McLeod, 1987). It thus seems that the novices, as well as the karate athletes, anticipated the target area of the opponent’s attack, although the 100-ms delay in choice RT reflects inferiority of the novices’ anticipatory skills. Abernethy and Russell (1987) drew a similar conclusion from their temporal occlusion experiments with badminton players.

The athletes were also slightly but significantly faster in the dot-stimulus choice-RT condition. This suggests that, in addition to the superior anticipatory skill, they have a better ability to make quick discriminations of two vertical locations. Why the athletes are better at the discrimination, and whether their better discrimination is specific to vertical locations or ubiquitous in space and other dimensions (e.g., Nou-

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1 The number of participants in this experiment, six athletes and seven novices, was small in comparison with the previous studies of karate performance (e.g., Kim & Petrakis, 1998; Rasch & Pierson, 1963; Scott et al., 1993). We attempted to compensate for the small number of participants by collecting a large number of data for each participant, 100–250 responses for each condition, in order to obtain reliable measures of performance that would differentiate between the athletes and the novices. More problematic in this experiment is the non-uniform levels of expertise in the athlete group and their difference in age from the novice group. In the athlete group, four of the six participants had 4–6 yrs experience of karate training and black belts, and the remaining two had only 1 yr experience of karate and no black belt. The mean age of the athlete group, 21, was younger than that of the novice group, 28, mainly due to the presence of the first and second authors (39 and 43, respectively) in the novice group. Such differences in level of expertise and in age are known to be significant factors affecting speed of information processing, reflected by RTs and PCRs (e.g., Abernethy, 1988; Cerella, 1985; Kim & Petrakis, 1998). To see whether the data of the two less experienced athletes and the two authors may have biased the overall results of this experiment, we analyzed the data of the remaining participants, four athletes and five novices. Their mean ages are now comparable to each other, 21 for the athletes and 23 for the novices. Statistical analyses replicated the results obtained from the original data sets with six athletes and seven novices. Main effects of Group, Stimulus, and Task and interactions between them are all significant. Significant differences between the athletes and the novices are seen in the choice RT task, but not in the simple RT task. It is thus safe to say that the results of this experiment are not subject to the non-uniformity in level of expertise and the age differences between the two groups.
gier et al., 1992; Whiting & Hutt, 1972) are not clear. One possibility is that the karate athletes have learned offensive and defensive techniques in terms of vertical levels (upper, middle, lower), so they may have become sensitive to vertical differences in space.

In contrast, the lack of significant difference in simple RT between the two groups, for either the dot or the video stimuli, implies that the athletes are no better than the novices in visual detection of a single dot or of any change in the static display of the opponent’s ready stance. As we discussed earlier, there are discrepant findings from studies using simple RTs in karate as well as in other sports, some showing faster RTs of expert athletes (e.g., Kioumourtzoglou et al., 1998; Layton, 1991) while others not (e.g., McLeod, 1987; Rasch & Pierson, 1963). The present experiment adds negative findings to the literature.

3. Experiment 2

3.1. Method

The apparatus was the same as in Experiment 1. The stimuli were identical to the 50 video stimuli of Experiment 1, except that their presentation was cut off at the seventh frame. This cut-off point was chosen in consideration of results of a preliminary experiment, which showed that the presentation of the first seven frames were sufficient for the karate athlete to make correct decisions in more than 90% of trials. The time sequence of one trial was similar to that of Experiment 1 with the video stimuli, except that after the seventh frame, the stimulus was replaced with a blank screen. After the stimulus presentation on each trial, the participants were given unlimited time to decide as accurately as possible whether the offensive action would be aimed at the upper or the middle level. For each participant, the data were collected in one session of 50 trials, each trial presenting one of the 50 stimuli in a random order. The 12 participants of Experiment 1 (six athletes and six novices; the first author was dropped from the novice group) also participated in this experiment.

3.2. Results and discussion

The mean PCR of the athlete group was 96% (SD = 2.0), which was significantly higher than that of the novice group, 80% (SD = 7.8), \( t(10) = 4.85, p < 0.01 \). This corroborates the results of Experiment 1 and supports that the faster RTs of the athletes in the video-stimulus choice-RT condition was due to their anticipatory

\[ ^2 \text{A similar result was obtained when the analysis was confined to the four black-belt athletes and the five younger novices (see Footnote 1). The mean PCR of the four athletes, 97.0\% (SD = 2.0), was significantly higher than the PCR of the five novices, 82.8\% (SD = 5.6), } t(7) = 4.79, p < 0.01. \]
skills, not to their decision making. Moreover, the accuracy data of this experiment enhance the choice RT data of Experiment 1 in helping us elaborate upon the anticipatory skills of the athletes and the novices. We assume that their anticipatory skills consist of (at least) two processes; extracting information from the early motion of the opponent’s attack and estimating from that information the target area (upper or middle) of the attack. In this experiment, the information extracted by the first process was limited to the first seven frames of the video stimuli. That the mean PCR of the athlete group is close to their value in the video-stimulus choice-RT condition of Experiment 1 (94.7%; for the four black-belts, 95.2%) suggests that their extraction process in the choice RT task was also confined to around the first seven frames, even though the subsequent frames were presented in the experiment. In other words, the athletes might be able to extract enough information from the first seven frames to estimate the target area of the opponent’s attack at over 90% accuracy irrespective of the experimental tasks used in the present study (i.e., RT and temporal occlusion tasks). On the other hand, the mean PCR of the novices was lower than their value in the choice RT task (94.7%, identical to the athletes'). In conjunction with the 100-ms delay of the choice RT from the athletes, this suggests that the extraction process of the novices worked on the first 10 frames, which corresponded to three extra frames, or a 100-ms delay (33 ms per frame), from the seventh frame suggested for the karate athletes. Accordingly, presenting only the first seven frames lowered their PCR in this experiment. Therefore, the main difference between the athletes and the novices seems to be in the information-extraction process, and not in the estimation process, of their anticipatory skills.

A couple of additional points should be noted concerning this experiment. First, cutting off every stimulus at the seventh frame may not be adequate because, as noted in Experiment 1, the stimuli may differ in minimum viewing time (or frames) necessary for the correct decisions. The termination at the seventh frame might be too short, or too long, for some of the stimuli. An alternative is to cut off each stimulus at the frame corresponding to its minimum viewing time. This is difficult to do in practice, however, because finding the minimum time for each of the 50 stimuli requires a series of experiments with careful manipulation of the viewing time and, even if we do this, the minimum viewing times would differ among participants. In fact, we analyzed the present data to see if particular stimuli induced more errors in the participant’s judgments, but there were large individual differences which prevented any meaningful conclusion. Second, because the same participants had taken part in Experiment 1, their prior exposure to the same set of stimuli may have contributed to the result of this experiment. One possibility is that the karate athletes may have better memory of karate-related events than novices, and the athlete’s clearer memory of the video stimuli, acquired from Experiment 1, may have helped their decisions in this experiment. Better recalls of sport-specific items by expert players have been reported in karate (Hodge & Deakin, 1998) as well as in other sports (Allard et al., 1980; Williams & Davids, 1995), and the results of Experiment 1 showed learning effects for the athletes as well as the novices. Further research will be needed to explore the possible effects of specialized memory possessed by karate athletes.
4. General discussion

The present study examined the expertise advantage of karate athletes in tasks with realistic and simplistic settings. Experiment 1 showed that the athletes responded faster than the novices in the video-stimulus choice-RT condition, which simulated the real stimuli and task of karate, indicating superior anticipation of the athletes regarding the opponent’s attack (Scott et al., 1993; Williams & Elliott, 1999). The athletes were also slightly but significantly faster in the dot-stimulus choice-RT condition, which was probably due to their better ability of vertical discrimination. The athletes were not different from the novices in simple RT to either dot or video stimuli, suggesting that the athletes were no better in visual detection not specific to karate. These results are consistent with a general consensus of sport research that the advantage of expert players is most evident in tasks with realistic settings that assess sport-specific perceptual skills, while their advantage is relatively small or non-existent in simplistic tasks used to examine basic sensory functions (Borgeaud & Abernethy, 1987; Helsen & Starkes, 1999; Starkes, 1987).

Experiment 2 provided supporting evidence for the athletes’ superior anticipation. In the temporal occlusion paradigm, the athletes were more accurate than the novices in decision making regarding the opponent’s attack. This result not only supports that the athletes’ faster RTs in Experiment 1 was due to their anticipation based on the early part of the opponent’s attack, rather than to their decision making (Chamberlain & Coelho, 1993), but it also suggests that the main advantage of the athletes may be in extracting necessary information from the opponent’s motion. These findings of the athletes’ anticipation fit well with practical aspects of karate, which place a great emphasis on the role of anticipation. Anticipation is particularly important in defence, for avoiding the opponent’s attack and for taking a proper position prior to the contact (Wilk et al., 1983), which reduces significantly the damage from the attack. Some training is focused on anticipating the opponent’s attack (Egami, 1976). It has been suggested that experience in training and games would enhance the athletes’ karate-specific knowledge base, resulting in their superior anticipation (Williams & Elliott, 1999).

Although the present findings add to our understanding of RTs and perceptual skills of karate athletes, some issues remain unanswered. One concerns cues in the opponent’s action that are used by karate athletes to anticipate the target location of the attack. Such cues may include changing positions of body parts (head, hands, feet etc.), concerting movements of those parts, or even gaze directions (see Figs. 1 and 2). Williams and Elliott (1999) recorded the participant’s eye movement during the RT task and found that both the athletes and the novices tended to fixate on the head and the chest of the attacking athletes in the video rather than on the arms and the fists. They suggested that the athletes, as well as the novices, used the central regions (i.e., head and chest) of the opponent’s body as “visual pivots” to distribute their attention over peripheral regions (also see Ripoll et al., 1995). Although this is an interesting suggestion regarding search strategy for anticipatory cues, it is not yet entirely clear what spatial and temporal aspects of the opponent’s motion
serve as reliable cues for quickly and accurately anticipating the location of the forthcoming attack. In Experiment 2 of the present study, we proposed that the athletes extract critical information from the first seven frames of the video stimulus, while the novices required 10 frames. This proposal fits the present data but needs to be verified with further experiments. Particularly, the exact number of frames necessary for them to reach a certain level of accuracy should be specified. One way to answer these questions is to manipulate the spatial and temporal occlusions of the videotaped opponent’s actions in the occlusion paradigm, which has been used in studies of other sports to identify advance cues utilized by expert players (e.g., Abernethy, 1990; Abernethy & Russell, 1987; for a review, see Williams et al., 1999).

Another issue is the differences between RTs in laboratory settings and actions in real situations. In Experiment 1, the athletes’ choice RTs to the video stimuli (mean 552 ms) are comparable to the completion time of videotaped offensive actions (430–660 ms), which means that their reactions would be too slow in real defensive situations. This points to important differences between the laboratory settings of the present study and the conditions of real situations. One is the response mode to the opponent’s attack. In the present study the athletes responded by a key press, while in real situations they would make defensive actions (blocking), which would be more natural for them to act against the opponent’s attack and probably faster than the key press. Indeed, Williams and Elliott (1999) showed that the athletes’ mean RTs for real defensive actions were around 300–400 ms, which appear to better represent the athletes’ RTs in real situations (also see Scott et al., 1993). The other is the presentation sequence of the offensive actions. In the present study, as well as in the study by Williams and Elliott (1999), the participants were randomly presented with separate actions of the three opponents. This is quite different from real situations, where each athlete is faced with one opponent for some period of time, so that the previous actions of the opponent may provide useful information for forthcoming attacks and facilitate defensive actions in terms of speed and accuracy. Another possibility is that in real situations, it may be too late once an opponent starts an offensive action. It is emphasized in the practice of karate to keep a proper distance (‘maai’) from an opponent, in order to prevent the opponent from making attacks. Anticipation alone may be insufficient and need to be coupled with other defensive strategies, such as keeping a proper distance. These points will be investigated in field studies or in laboratories with more realistic settings.

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