Enhancing the decision making of skilled karate athletes with a "no-feedback" perceptual training program

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Abstract

Background & Study Aim: In combat sport, anticipation is an indispensable quality in order to avoid being hit. The aim of this study is knowledge about the efficacy of a "no-feedback" video-based perceptual training program for enhancing the decision-making of skilled male karate fighters.

Material & Methods: This study examined the effectiveness of a "no-feedback" video-based perceptual training program to enhance decision-making of skilled karate fighters (n = 6) compared to control group (n = 6) and placebo group (n = 6). Participants in the intervention group completed six training sessions where they reacted to temporally occluded video footage of typical combat situations during which they had to mime, as rapidly and accurately as possible, the action which they would have carried out in the observed situation. Decision time and decision accuracy were assessed pre- and post-intervention and during acquisition. Number of action rules was recorded pre and post the implementation of the program.

Results: Participants who received "no-feedback" video-based perceptual training significantly enhanced their decision accuracy and decision time during the period of the program and from pre- to post-test compared with both control and placebo group. Moreover, the absence of an increase in the number of verbalized action rules after the video training suggests that this approach may have promoted implicit learning.

Conclusions: "No-feedback" video-based perceptual training program is an effective approach to enhance decision-making of skilled karate fighters without the accrual of explicit knowledge.

Keywords: decision time · implicit learning · skilled performance · video-based test

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Decision making – ability of an athlete to quickly and accurately select the correct option form a variety alternatives [33]

Implicit learning – non-intentional, automatic acquisition of knowledge about structural relations between objects or events [34]

Introduction

A number of research teams have demonstrated the superiority of experts in making rapid and accurate decisions in the course of their actions [1,2]. This superiority is argued to stem from exceptional perceptual and cognitive skills possessed by the experts. These perceptual-cognitive skills are displayed in processes that require the encoding, synthesis and interpretation of domain-specific information, such as selective attention and pattern recognition [3]. In the case of combat sports, such as karate, experts are able to move earlier (appearing unhurried) because of optimized attunement to anticipatory information sources in the task environment. Anticipation is an indispensable quality for defence in order to adapt one's actions before the contact with the opponent's strike [4]. A number of studies have demonstrated for expert fighters that the movement time to strike a target was shorter than the reaction time to dodge [5,6]. As such, it seems obvious that learning to interpret the movements of an opponent in order to better "read" his actions and not be hit, is an important element in combat sports [7-9].

In the last decade, video-based perceptual training has demonstrated a number of advantages for the optimization of these perceptual-cognitive skills [1,10,11]. Accordingly, this training method could enhance the decision making accuracy of athletes by favouring the recognition and understanding of specific sporting situations. When a player trains using a video-based perceptual training approach, he is asked to interact with the environment with which he is presented. The video footage is presented either from the angle of the sportsman who is undergoing the training session or from a point of view that is outside the training situation. The training sessions usually consist of a range of video clips that present different types of situations or the same situation in different conditions. When a decision-making moment is considered to occur, the image is paused (occluded). At this moment, the participants are required to decide, as rapidly and accurately as possible, the actions that they would undertake in the observed situation. Some authors have demonstrated the efficacy of this method in terms of improving the reaction times and/or improving the number of accurate responses of the athlete in visual simulation environment [12-14] as well as in on-field performance [15-17]. However, the accumulated evidence to date has been accrued with learners. A focus of the current experiment was to ascertain the relative value of such training for skilled competitors.

Broadening the extensive work on implicit motor learning approaches [18] a more recent direction within the perceptual training literature has been the presentation of the video-based scenarios designed to elicit the benefits of implicit learning [10,19]. An explicit learning approach provides specific instructions about the sources of information pertinent to the anticipation of a specific situation. Such an approach also results in the acquisition of a verbalizable knowledge base about the information sources being attended to. During video-based perceptual training, in order to encourage an explicit learning mode, the video sequence (i.e. the game sequence) is typically shown a second time where the full game sequence is replayed so that the learner can judge the accuracy of his decision. In addition to this, between each video sequences the coach can help the athlete make a connection between the information gleaned from observation of the action and the result of that action. For example, the coach can indicate to the player the positions of the playmate on the screen or the different postures or positions of an opponent and thus lead him to associate with each position, a game sequence or "if-then" rules. The goal of this type of training sequence is to increase the quantity of explicit knowledge of the learners so that they can more readily understand the meaning of information picked up in the environment. Results show that explicit instructions favour rapid acquisition of conscious and verbalizable knowledge [19].

In contrast, an implicit learning approach results in the development of anticipatory skill without the concurrent acquisition of explicit knowledge about the important information sources. During video-based perceptual training, in order to encourage an implicit learning mode, researchers have removed verbal instructions and just encourage participants to focus their attention on potential areas of interest that may anticipate the outcome of situations. A number of studies have shown significant improvements in decision time and decision accuracy after the implementation of this type of implicit perceptual training program [1,10,16]. The goal of this approach is to minimise the accumulation of explicit knowledge and also the propensity of participants to reinvest knowledge during performance which could upset the automatic execution of gestures, which is all the more important if the situation is stressful [20]. For example, Smeeton et al. [19] found that decision-making performance was more robust under anxiety-provoking conditions when participants were training using more implicit perceptual training, compared to an explicit learning approach. In this sense, the implicit approach could be particularly recommended with skilled athletes who are frequently subjected to high pressure situations. Despite this purported value, very little research has examined the nature of implicit learning within skilled players.

During learning, explicit processes use working memory to identify and correct errors during the learning process so as to only store relevant information [21]. Typically, learners conceive and test hypotheses in a strategic trial and error fashion. Masters [22] argued that implicit processes would encode new information without the involvement of working memory. One method proposed by Masters to potentially elicit implicit learning, is by removing visual feedback (i.e. knowledge of results). Therefore, learners would be unable to test the relevance of decisions and the concomitant increase of explicit knowledge would be minimal. However, no study in the perceptual training literature, as far as we know, have showed the relative effectiveness of a "no-feedback" perceptual video-based training approach (i.e. without verbal instructions and visual feedback) in enhancing decision-making skills. Accordingly, this is a key issue to be addressed in the current study.

The aim of this study is knowledge about the efficacy of a "no-feedback" video-based perceptual training program for enhancing the decision-making of skilled male karate fighters. It was hypothesized that results would show a significantly enhanced performance from pre- to post-test compared with both control and placebo groups and during the acquisition phase as illustrated by a faster decision time and an increase in decision accuracy. Furthermore, if the learning was implicit, the number of explicit rules accrued as a consequence of the training will not have increased by the end of the training period.

Material and Methods

Participants

Eighteen skilled male karate fighters consented for the study ("no-feedback" perceptual training group: n = 6; control group = 6; placebo group = 6). All athletes practiced approximately 10 hours per week and had been competing for an average of 10 years. All participants were aged 23 to 31 years (M_{age} = 26.4 ± 3.1 years old). The study had ethical clearance according to the relevant institutional guidelines, and informed consent was obtained from participants prior to commencing the experiment.

Procedures

Test and training films construction. The footage used during the video-based test and video-based training sessions, presented sequences of international level combats filmed at fighter eye level, at a distance of 5m from the centre of the mat. This perspective provided vision of the two fighters at the same time. The film sequences were edited to produce 30 trials for video-based tests and 180 sequences for video-based training sessions. Footages chosen for test films were different than those for training films in order to control effects of familiarity. All the video sequences were constructed by one expert coach. Then each test and training sequence was submitted for the approval of two other coaches with international qualifications. In this way, coaches have to rated each sequences of combat through the use of a Likert-type scale ranging from 0 to 3 (1 point for each criteria: Perspective, time of occlusion, clarity of situation). Only those sequences that were rated above 2 by all two coaches were used to produce test and training films.

The video-based test and training was made up of 30 different scenarios (clips) each separated by inter-trial interval making a total video time of around 8 minutes. In the video sequences the participant was required to place himself in the role of one of the two fighters. For this, before the beginning of each sequence, a blue or red figure appeared on the screen and indicated to the athlete whether he was the fighter with the blue or red belt. For example, if the figure was blue the athlete had to become the blue belted competitor on the screen. Then a fight sequence which lasted between 4 and 10 seconds was played out to participants. The footage was then interrupted by a black frame at a point that was considered appropriate by the coach for making a decision.

Figure 1. An example of test/training video footage (see "no-feedback" perceptual video-based training program, which tutorial video is available at the website of the journal Archives of Budo (www.archbudo.com) in the left menu (section: ArchBudo Academy) under link No-feedback perceptual training (http://www.archbudo.com/text.php?ids=101055).

This occlusion corresponded to one of the three following situations which have been randomized in the video-based test and video-based training sessions: after the beginning of an attack by the opponent (at the moment of the translation of the centre of mass of opponent forward), during a move (at the moment when the opponent no longer has support from the floor when he is crossing his legs or at the moment of the second leaning of the forward leg on the floor), after a fake movement repeated twice. Thus, the film sequences contained 10 attack sequences, 10 move sequences and 10 fake movement sequences. The 10 attacks consisted of two repeats of each of five attacks delivered to two distinct spatial targets: a rear hand straight punch to the solar plexus, a rear hand straight punch to the head, a front hand straight punch to the head, a rear foot circular kick to the solar plexus, and a front foot circular kick to the head. The 10 move sequences consisted of five repeats of each of two types of move: a side move and a change of position. The 10 fake movements consisted of five repeats of each of two types of fake movements: a body fake movement and a front circular fake kick. This way, the diversity of the scenarios presented provided a sufficiently complex context that competition karate combats. To remove situational probability information, only one action was performed by the opponent on the screen just before the occlusion. In order to prevent the athletes from consciously verifying their decision accuracy (as per an explicit learning approach) the result of an action sequence was not presented in a second showing of the video footage as is typical in most perceptual training literature.

Training program. Participants were divided randomly into two groups – a "no-feedback" video-based perceptual training group, a placebo group and a control group.

The training program occurred over 6 consecutive weeks with a weekly video training session. In total, the athlete's viewed 180 action sequences. All sequences shown were different. The film sequences were presented to participants using a video projector (Sony KP44 PX2, Japan) on to a 3 x 2 m wall in order to recreate the scale of the visual conditions experienced in the real world setting. Each training session was completed in a squad training session, undertaken on the same day of the week in the same room at the same time. During the training sessions the participants were positioned 2.50 m away from the wall in a fighting stance (a ready to hit position) and hopping as is customary in shadow fighting. At the pause of the video fight sequence, the athlete had to mime the action that he would have taken had he been in the fight situation that he was observing. The athlete was instructed to make the most accurate response as quickly as possible. To favour implicit learning processes, no instructions were given during or after the training sessions. Each session was filmed by a camera placed to record both the video projection of the fight situations and each of the participants' decisions. For each trial of each training session, the decision accuracy as well as decision times were measured.

Participants in placebo group watched sequences of international high level combats (i.e. 2012 world championship, 2011 US open competition, 2012 Paris open competition) for a length of time (8 min) equivalent to the duration of the perceptual training sessions undertaken by the "no feedback" experimental group. To maintain their attention, the participants in this group were asked questions at the end of the training session about the combat they had been watching. Typical questions included: What point is scored at the end of the combat? What are the favourite attacks of this fighter? What is the specific tactic used by this fighter? What are the strengths and weaknesses of this fighter? What tactics would you use to win against this fighter? Additionally, this group was given information about the expected positive effects of increased combat knowledge on decision-making performance.

Participants in control group were required only to complete the two test sessions (no additional video-based perceptual training sessions). However, all participants of the study completed the same on-mat training program.

Video-based test. Participants performed the same test twice, prior to a 6-week training intervention (pre-test) and shortly after the completion of the training intervention (post-test). Video-based test was completed exactly in the same conditions of training sessions. The athlete was instructed to make the most accurate response as quickly as possible. Each test was filmed so as to allow the analysis of decision times and of the decision accuracy in each scenario.

Dependent measures

Decision time was defined as the length of time (in milliseconds) between the frame immediately after occlusion and the participant's first definitive movement in any direction. This was calculated post-hoc using frame-by-frame analysis of video footage recorded at 25 Hz. A negative decision time was recorded when participants initiated the move before the occlusion. In addition to this, the first author (international-level competitor) evaluated the decision accuracy for each sequence using two independent criteria: "blocks" and "attacks". One point was awarded if the block prevented the attack from touching the participant. In this situation, participants have the choice between 4 decision-alternatives: to block up, down, right or left. Another point was given if the attack enabled the participant to touch the opponent on the screen. In this situation, participants have also the choice between 4 decision-alternatives: to hit the nose, the left ear, the right ear, the plexus solar and the back. Eventually, participants have the choice between 8 decision-alternatives through multiple karate techniques. No point was awarded when the athlete did not initiate any action. Decision accuracy was evaluated for each participant, at each training session from a total of 60 points (30 video clips x 2 points). For decision accuracy randomly selected trials (n= 100) were recorded by the same experimenter and an expert coach in order to assess the reliability of results. A high interclass correlation was found between coders (r = .93). Finally, a question sheet regarding the rules of action was completed by participants at the commencement and conclusion of the 6 week training intervention. They were asked to identify key factors of the sequence that influenced their decision in an attack or a counter attack. The pre-post training variations in the number of verbalizable rules concerning anticipation of the action sequence were analysed to evaluate the impact of training on the accumulation of explicit knowledge. Thus every new rule with regard to anticipatory cues or pattern-recognition principles was considered as the formulation of an explicit rule. This method has been used a number of times in order to measure the efficacy of implicit programs [10].

Statistical analysis

Decision time and decision accuracy from the video-based test sessions were analysed separately using 3 x 2 (Group x Test) mixed-design analysis of variance (ANOVA) tests with repeated measures on the last factor. This procedure was used to compare the pre- and the post-test performance. Decision time and decision accuracy from the video-based training sessions were analysed separately using 1 x 6 (Group x test) mixed-design analysis of variance (ANOVA) tests with repeated measures on the last factor. This procedure was employed for comparison between each training session. All relevant assumptions for ANOVA were checked and appropriate corrections made if a violation was found. The results from the verbal rule question sheets were evaluated by two independent ratters. Responses to questions were assessed to determine the number of rules reported by each participant. The final tallies of each ratter were compared and any major disparities were discussed and then adjusted after agreement had been reached. Correlational analysis was used to assess the degree of consistency between the two ratters after the adjustments. A 3 x 2 (Group x Test) mixed-design ANOVA with repeated measures on the last factor was then used to analyse the results. For all analyses, significance was achieved if $p \leq .05$; any significant results were followed up with post-hoc analyses, adjusted where appropriate using the Bonferroni correction factor.

Results

Video-based test

Results from a one-way ANOVA on the pre-test data indicated that there was no significant difference

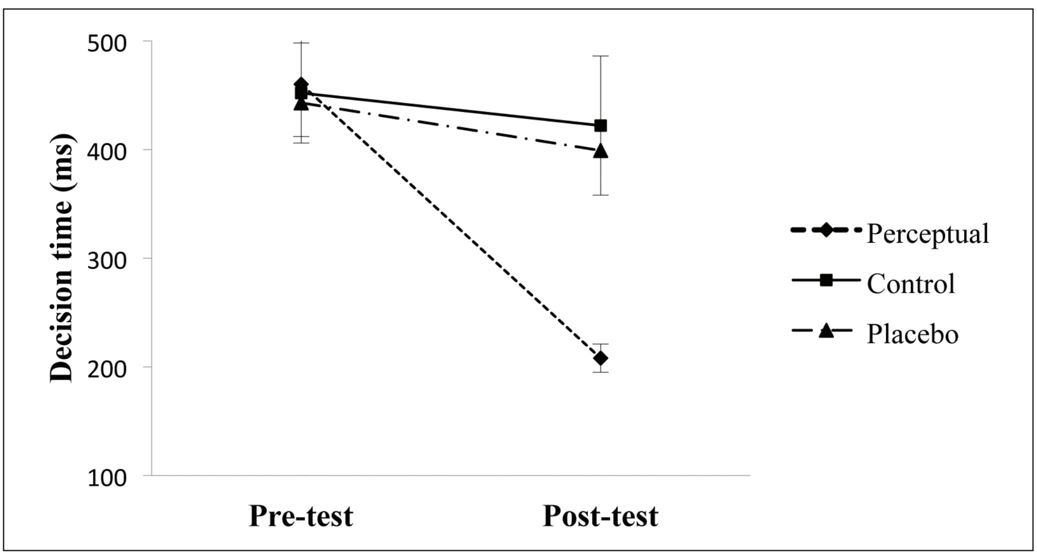

Figure 2. Decision time (ms) with error bars across groups at pre-test and post-test (in each groups n = 6)

between the groups at the start of the experiment for decision time, $F(2, 15) = .17$; $p = .85$; $\eta_p^2 = .02$, and decision accuracy, $F(2, 15) = .61$; $p = .56$; $\eta_p^2 = .07$.

Decision time. Analysis of decision time during the video-based decision-making test indicated a significant interaction between training group and time of testing, $F(2, 15) = 45.59$; $p < .01$; $\eta_p^2 = .86$. A post-hoc Boneferroni showed that "no-feedback" video-based perceptual training group performed better than both control and placebo group ($p \leq .05$). In addition, post-hoc analyses highlighted a significant decrease of decision time for the perceptual training group only, between the pre-test (M = 459.8 ± 48.5 ms) and the post-test (M = 207.8 ± 12.7 ms). No significant difference was found between control group and placebo group on post-test (Figure 2).

Decision accuracy. Analysis of decision accuracy during the video-based decision-making test showed a significant interaction between training group and time of testing, $F(2, 15) = 50.6$; $p < .01$; $\eta_p^2 = .87$. A post-hoc Boneferroni showed that "no-feedback" video-based perceptual training group performed better than both control and placebo group ($p \leq .05$). In addition, post-hoc analyses revealed a significant improvement of decision accuracy for the perceptual training group only, between the pre-test (M = 23.5/60 ± 7.7/60) and the post-test (M = 52.8/60 ± 2.5/60). No significant difference was found between control group and placebo group on post-test (Figure 3).

Training session

Decision time. Analysis of decision times from the first to last training session indicated a significant main effect for training, $F (5,25) = 28.75$; $p < .001$; $\eta_p^2 = .85$. Results showed a general enhancement in decision-making performance occurred for all participants between the first training session (M = 355 ± 60.3 ms) and the last training session (M = 213 ± 10.7 ms) after the 6-week program (Figure 4). In particular, Bonferroni corrected post-hoc analyses demonstrated significant reductions in decision time ($p < .01$) between the 1st training session and each other session and the 2nd training session and each other session (except the session 3). No significant improvements were found after the 2nd training session.

Descriptive analysis of inter-individual decision time performance highlights small differences between participants (Figure 5). Overall, the decision time of each athlete decreased during the sixth training sessions and stabilizing at approximately 200 ms. The largest differences between athletes were recorded during the first phase of the program. For example, Participants 4 and 5 enhanced their decision time much more quickly than the other participants. Participant 5 enhanced decision time by 177 ms, starting from 385 ms during the first session and recording 208 ms on the third session. Meanwhile, participant 6 only gained 83 ms, going from 450 ms to 317 ms. Similarly, participant 4's decision time decreased by 104 ms between the 1st and the 2nd training session while participant 3 only lowered his decision time by 28 ms.

Decision accuracy. Analysis of decision accuracy from the first training to last training session indicated a significant main effect for training, $F (5,25) = 19.07$; $p < .001$; $\eta_p^2 = .79$. Similar to decision time results a

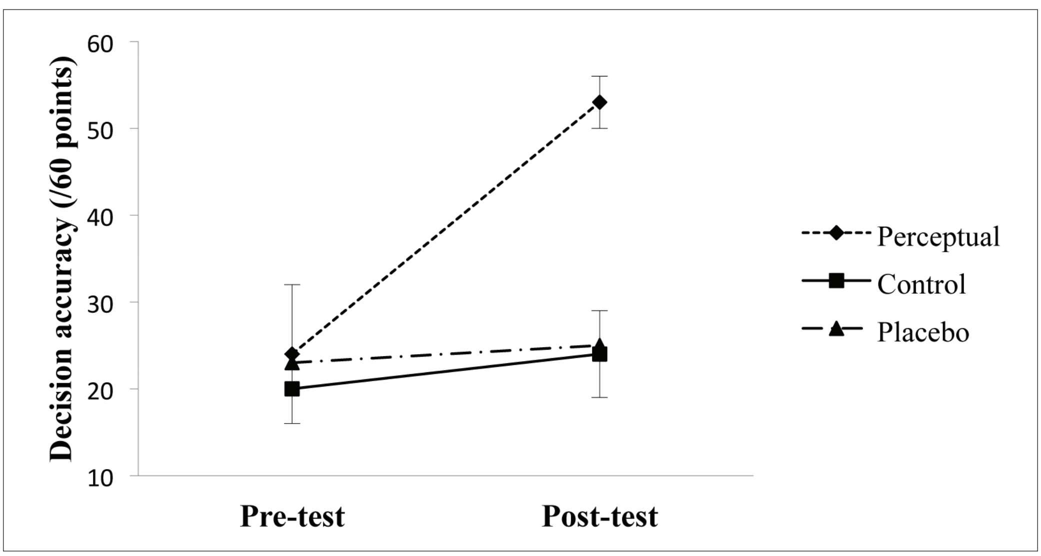

Figure 3. Decision accuracy (/60 points) with error bars across groups at pre-test and post-test (in each groups n = 6)

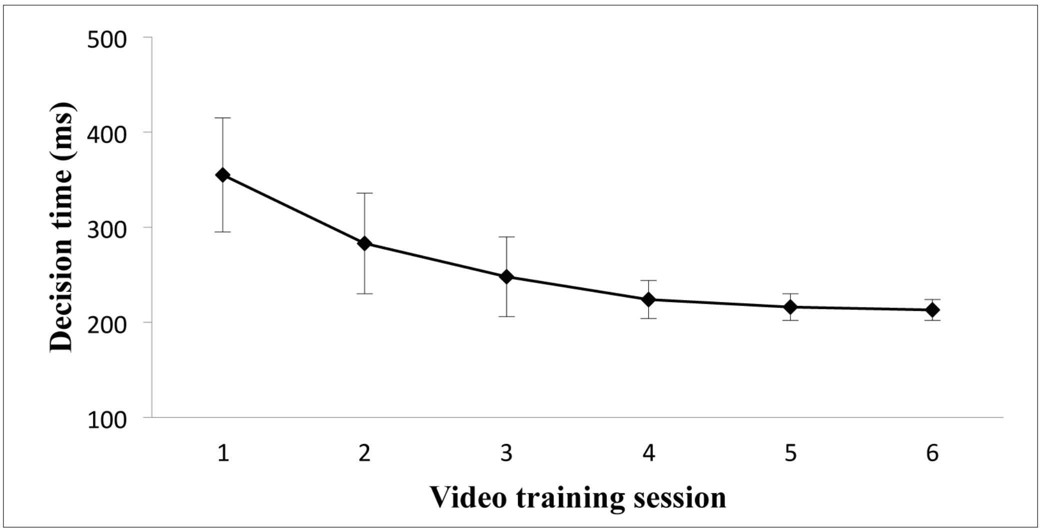

Figure 4. Decision time (ms) with error bars per training for no-feedback perceptual training group (n = 6)

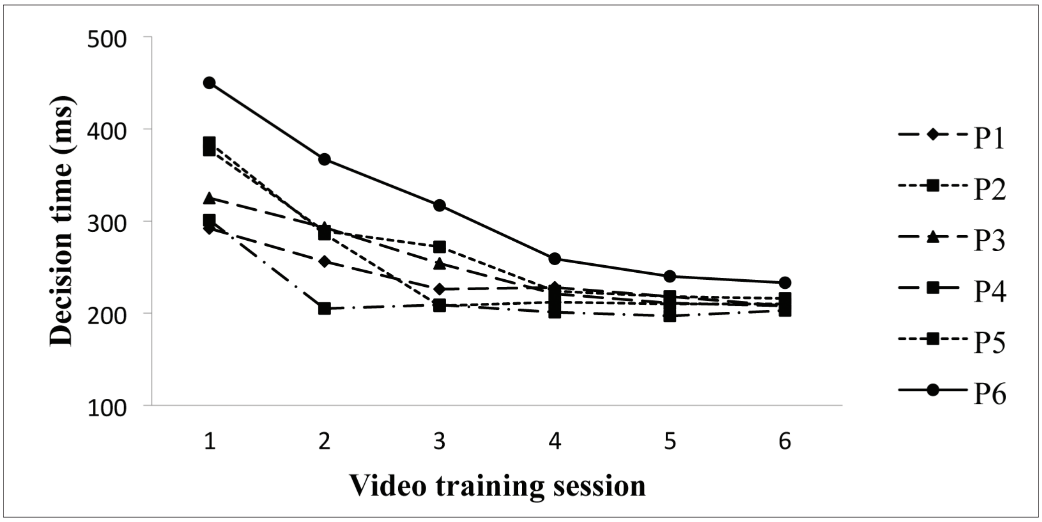

Figure 5. Decision time (ms) per training for no-feedback perceptual training group (n = 6)

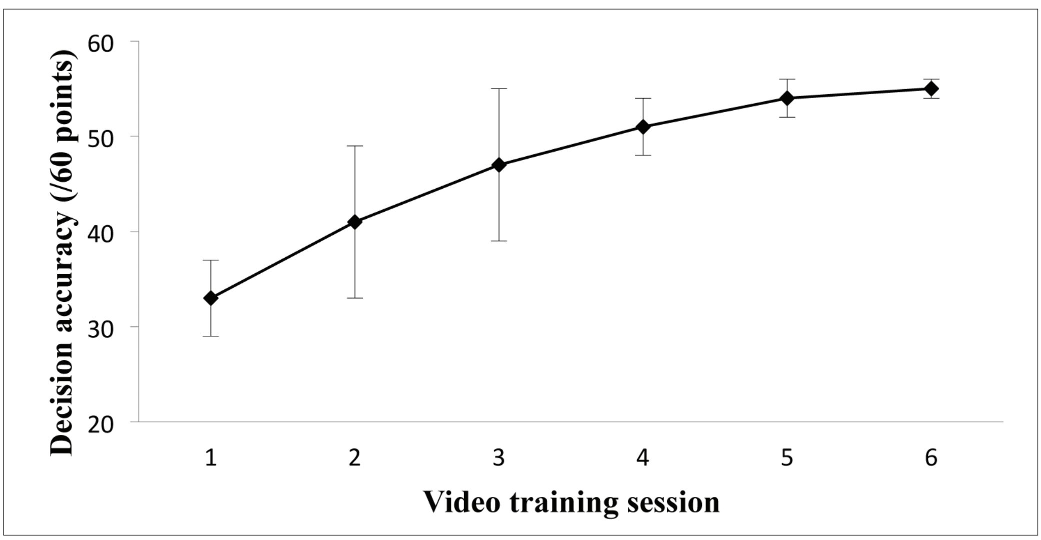

Figure 6. Decision accuracy (/60 points) with error bars per training for no-feedback perceptual training group (n = 6)

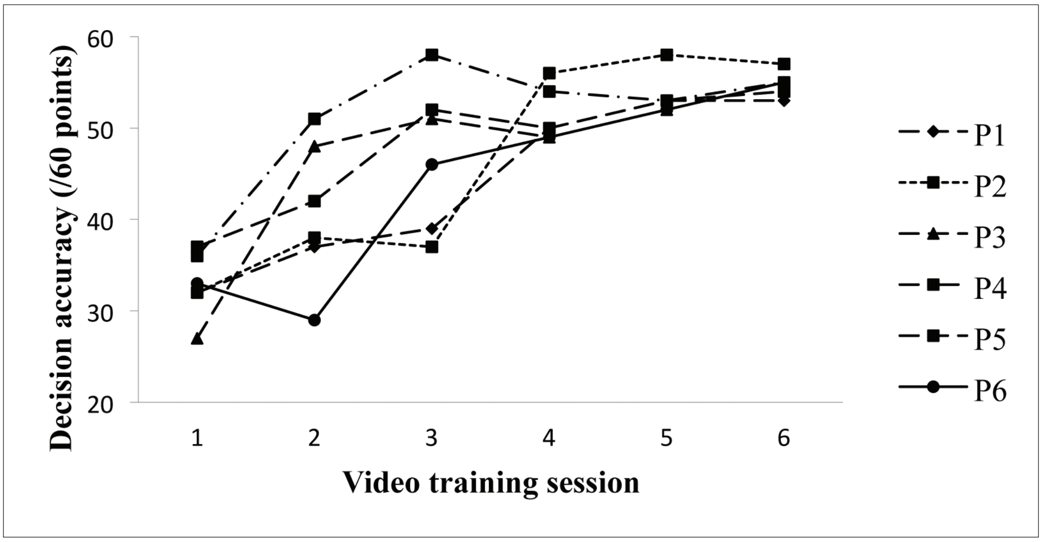

Figure 6. Decision accuracy (/60 points) per training for no-feedback perceptual training group (n = 6)

general enhancement in decision-making performance occurred for all participants between the first training session (M = 32/60 ± 4/60) and the last training session (M = 55/60 ± 1/60) after the 6-week program period (Figure 6). In particular, the Bonferroni corrected post-hoc analyses revealed significant increases in decision accuracy ($p < .01$) between the 1st training session and each other session and the 2nd training session and each other session (except session 3). Again, no other significant improvements were found after the 3rd training session rather participants seemingly consolidated the level of performance attained.

Descriptive analysis of inter-individual decision accuracy performance highlights global inconsistency during the program (Figure 7). For example, each athlete recorded at least two performance decreases from one session to the next. In addition, for the decision time, decision accuracy varied considerably among participants during the first half of the program. For example, between the first and the third session, participants 3 and 4 increased their decision accuracy by 40 % ($M_{DA\ 1st\ training}$ = 27/60; $M_{DA\ 4th\ training}$ = 51/60) and 37 % ($M_{DA\ 1st\ training}$ = 36/60; $M_{DA\ 4th\ training}$ = 58/60). At the same time, Participants 1 and 2 only raised their performance accuracy by 12 % ($M_{DA\ 1st\ training}$ = 32/60; $M_{DA\ 4th\ training}$ = 39/60) and 8 % ($M_{DA\ 1st\ training}$ = 32/60; $M_{DA\ 4th\ training}$ = 37/60). However, participants with the largest decision accuracy increase were those with the lowest performances at the beginning of the program.

Action rules

Analysis of action rule question sheets completed by all participants both before and after the intervention period indicated that there were no significant effects for time of testing, $F(1, 15) = 3.05$; $p = .10$; $\eta 2 = .17$, group, $F(2, 15) = 0.5$; $p = .09$; $\eta_p^2 = .01$, or the group by time-of-testing interaction, $F(2, 15) = .85$; $p = .45$; $\eta_p^2 = .10$. The results highlight that there were no significant differences in the number of rules reported from "no-feedback" perceptual training group between pre-test (M = 7.8 ± 2.5) and post-test (M = 8.3 ± 2.3) after the 6-week training period. Despite an equivalent level of expertise, descriptive analyses from inter-individual action rules revealed significant variation among athletes. For example, participants 1, 2 and 5 from "no-feedback" video-based perceptual training group reported twice as many action rules as participants 3 and 4 (Table 1).

Table 1. Action rules per participants for no-feedback perceptual training group across time of testing

No-feedback training group	Action rules	
	Pre	Post
Participant1	10	11
Participant 2	10	10
Participant 3	5	7
Participant 4	5	5
Participant 5	10	10
Participant 6	7	7

Discussion

This study examined the effectiveness of a "no-feedback" video-based perceptual training program to enhance decision making of skilled male karate fighters. We hypothesized that perceptual training that forced anticipatory judgments of action sequences without feedback could enhance decision times and increase decision accuracy of the participants without the accrual of explicit information. The results were supportive of these hypotheses.

These results could be explained by the optimization of situation-recognition processes. Thus, through repeated exposure to a variety of combat scenarios the participants learned to identify and interpret environmental cues in order to better understand the situation. For example, as training progressed the fighters anticipated the moment of occlusion by moving forward more frequently suggesting that the fighters became able to spot the defensive positioning of the opponent and his placement on the mat for predicting future actions or counterattacks. Similarly, while not directly measured in this study, it is also likely that the performance increase was a result of the participants better reading of the kinematic information displayed within the opponent's movement. Indeed, some studies have shown the superiority of experts in picking up salient information from the relative motions of the body and using this information to interpret and anticipate effectively the intentions of the opponent [23].

In the bulk of implicit video-based perceptual training literature, authors have removed explicit instructions to participants but provided them visual feedback about the correct decision (i.e., knowledge of result). This is the first time, as far as we know, that it has been show that a "no feedback" perceptual training program can lead to significant improvements in decision-making performance with elite athletes. However, it is crucial to note that training intervention in this study takes place as group training sessions. Thus, it is possible that participants were able to evaluate their decisions with those of other individuals and in the context of the group as a whole. In this way, athletes may have a relevant feedback to increase their decision accuracy and decrease their decision time.

A "no-feedback" training approach was utilized to examine whether participants could improve their anticipatory performance without the increase of explicit rules to guide this improvement. Results demonstrated that this was the case as there wasn't a significant increase in the total verbalizable knowledge articulated by the participants from "no-feedback" video-based training group between the beginning and the end of the intervention, which suggests a more implicit learning process was adopted during the training period. Interestingly the number of action rules reported for this skill group was consistent with the number of explicit rules typically reported by novice level explicit learning groups in the implicit motor learning literature [24]. What remains unresolved is whether this was due to the fact that the athletes already possessed a significant number of action rules and hence hit a ceiling level in this measure. A further prediction argued by Rendell et al. [25] is that if skilled performers completed an appropriate (large) amount of implicit practice they would actually reduce the number of action rules they possess. No support was found for this in the current study, where the athletes accrued 180 practice repetitions.

A relatively unique contribution to extant literature was the demonstration of the improved decision-making skill within a highly skilled athlete population. While these athletes were performing at a high level, it seems that they had not reached the maximum of their perceptual-cognitive skills [26]. Few studies have shown similar improvements in highly skilled athletes [11,16,17,27]. However, as is the case with many experiments involving highly skilled performers the current study was not without limitation. Due to the period of testing and training needing to compliment competition periods and the occurrence of injuries frequent in this population, our sample of athletes was small. However, appropriately there is an ever-increasing body of sport expertise literature relying on single-subject or group analyses to better understand the processes used by highly skilled performers [28].

A particular strength of this study was the session by session analysis of performance. Such results allow us to refine existing conclusions in the literature regarding how much and how long perceptual training is needed to demonstrate a positive response. Previous research has indicated significant progress after 45-60 minutes of exposure to video-based perceptual training with explicit instructions [14,29] or 90 minutes with implicit training [19]. In the current study we noted a significant enhancement of decision time and of decision accuracy until the completion of the second training session, that is to say after 20 minutes of training or 60 practice trials. These results are comparable with those of Poulter et al. [30] and Salvelsbergh et al. [31] who found a significant effect of training on performance after 20 minutes of perceptual training (120 trials) and 96 trials respectively, albeit with different skill level populations. Our data are consistent with the perceptual-cognitive training literature which reported the possibility of a ceiling effect in the acquisition of perceptual-cognitive skill for the experts who have been repeatedly exposed to the perceptual stimuli in the natural setting [32]. However, while the session by session performances were not statistically different there was still improvement in performance (Figures 4, 6) after session 2. These enhancements may still be considered crucial for elite athlete as only slight performance improvements can be the difference between winning or losing a championship medal. Moreover, individual analyses revealed some differences in learning speed among athletes. Indeed, it appears that athletes learned at different rates at the beginning of the program, the lower skilled performers improved more rapidly. For example, between the first and the third sessions, the decrease in decision time for participants 4 and 5 was twice that of participant 2 and 6. During the same period of time, decision accuracy in participants 3 and 4 increased almost of 40 % while participants 1 and 2 did not improve. After the sixth training session individual gains were smaller and differences among athletes smaller too. We did not investigate retention effects in the current study but it's interaction with the duration of the training period would be an obvious further issue to explore.

The utilisation of video-based perceptual training in combat sports opens up many opportunities. For example, one could ask a fighter to train against a specific opponent as preparation for an upcoming competition. Thus the participants could better read their opponent's game, better understand his way of fighting and ultimately better anticipate his movements. Further video-based perceptual training could be used to help a coach identify an athlete's strong or weak points such as being more or less successful in counter attacking when he has his left leg forward or whether he doesn't make rapid decisions about the repositioning of the opponent. One could therefore adapt the video-based perceptual training through the introduction of a scoring system which evolves before each video sequence. This initiative could enhance the heterogeneity of decision-making by inciting a choice of different options in identical situations but at different moments in the fight or at different scoring levels. Finally, a constant need within the perceptual training literature is to study demonstrate the transfer of anticipatory skills developed in the visual simulation setting to on-field performance [15].

Conclusions

This article is a unique contribution to show the efficacy of a "no-feedback" video-based perceptual training program to enhance decision making performance in elite karate fighters. The improvement in decision time and decision accuracy observed for perceptual training group compared with both control and placebo group should encourage coaches to use video-based simulations in addition to on-mat training sessions in combat sport. Moreover, the session by session analysis of performance highlighted significant enhancement of decision-making performance after 20 minutes of training and suggest that coaches could implement very short perceptual training program to enhance perceptual skills of elite athletes. Furthermore, the results confirmed that a "no-feedback" training approach was implicit enough to prevent the significant accumulation of explicit knowledge. Implementation of implicit approach is particularly relevant to reduce the athletes' propensity to reinvest knowledge during a performance which could upset the automatic mechanism of decision making, even more so in a stressful situation. As a consequence, using a "no-feedback" training approach is recommended for training skilled and high-skilled athletes who are frequently subjected to high-pressure situations.

Highlights

Video-based perceptual training enhances decision making of elite karate fighters.

No-feedback training is an effective approach to prevent the accrual of explicit knowledge.

Analyses from action rules revealed significant variation among elite athletes.

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Competing interests

The authors declare that they have no competing interests.

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