Comparison of a Video and a Virtual Based Environment Using the Temporal and Spatial Occlusion Technique for Studying Anticipation in Karate

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Abstract

Perception and anticipation are important determinants in karate sports. Using the temporal and spatial occlusion technique in video presentations is a common method to determine anticipatory cues but the lack of information about depth in video presentations seems to affect the results. The aim of this study is to compare the responses of karate athletes to occluded attacks shown on a video screen and in a virtual environment. Five expert karate athletes were filmed by two synchronized high-speed cameras while responding to nine temporally and spatially occluded sequences of a competition relevant attack at first in a CAVE (Cave Automatic Virtual Environment) and then on a life-size video screen. Their responses were rated as ‘correct’ or ‘incorrect’. The results of the Wilcoxon test show significant differences (Z = -2.325, p <.05) in regard to the number of ‘correct’ responses for these scenarios. It is concluded that the higher number of ‘correct’ responses in the virtual environment is caused by depth information, which evokes a more realistic feeling about the environment and is therefore seen as more beneficial for research of anticipation. Also, first anticipatory cues based on the results of the virtual environment could be determined.

KEYWORDS: ANTICIPATION, KARATE, OCCLUSION, VIRTUAL REALITY

Introduction

Anticipation is a performance-dependent factor in sports. In general, it is defined as a person’s ability to “foresee an action, an effect of an action or a dynamical changing environmental condition” (Munzert, 2003); in sports this can be the movement of a ball, a team mate or an opponent. Anticipation of human movements is based on the perception and recognition of cues within kinematic patterns, which are commonly learned by experience and training. Recent studies revealed that an early recognition of anticipatory cues depend on the level of expertise (e.g. Blake & Shiffrar, 2013; Jones, & Miles, 1978; Williams, 2004). Anticipation is especially important in fast ball sports, such as racquet sports, since the initiation of an appropriate movement must occur before racquet-ball contact, in order to achieve an on-time and successful response (Abernethy, 1987; Cauraugh, 2002; Goulet, Bard, & Fleury, 1989; Savelsbergh, Williams, Van der Kamp, & Ward, 2002; Williams, Ward, Knowles, & Smeeton, 2002; Williams, 2009).
A common method to identify anticipatory cues is the usage of video presentations combined with the occlusion technique (Davids, Savelbergh, Bennett & Van der Kamp, 2002). Two different types of occlusion methods can be distinguished: the temporal and the spatial occlusion. The temporal occlusion method crops visual presentations completely at certain points in time, while the spatial occlusion method only masks specific sections of a display covering up parts of the human body or objects. The method’s general purpose is to withhold specific visual information of the presentation to which the participants have to respond, either verbally, in written form or physically. The aim of this method is to detect which occluded information is important, based on the participant’s responses. Bad or out-of-the-order-responses at specific occlusions are seen as indicator for important information being withheld covering up an anticipatory cue. The number of correct responses to the temporal occlusions allows the detection of the occurrence of cues over time and the responses to the spatial occlusions of the location of the cues (Abernethy, 1987; Clatworthy, 1991; Jones & Miles, 1978; Mori, Ohtani, & Imanaka, 2002; Panchuk & Vickers, 2009).

One of the first studies using the temporal occlusion method was conducted by Jones & Miles (1978) and Isaacs & Finch (1983) in tennis. In their studies the participants had to verbally predict the ball’s landing position based on slides revealing information about a tennis serve before, during and after ball contact. The results are the same in both studies: unlike novices, expert tennis players are able to perceive and use early cues to predict the ball’s landing position. Abernethy & Russell (1987) also used the temporal occlusion method for presenting badminton serves on a video screen. While they were able to identify the point of time of anticipatory cues, they were unable to determine its location, e.g. body part or specific movement. In another study in squash, Abernethy (1990) used both, the temporal and spatial occlusion method, to identify the time and spatial location of cues of a serve. The results show that only experts are able to pick up information of the opponent’s arm movement before ball contact in order to anticipate the stroke direction. Savelsbergh, Van der Kamp, Williams, & Ward (2005) analyzed anticipatory skills of novice and expert soccer goalkeepers to temporally occluded penalty kicks on a video screen. The goalkeepers had to predict the ball’s landing position in the goal using a joystick. It showed that experts predicted the direction the ball flies concerning height and side better than novices. Williams (1997) and Williams, Davids, Burwitz, & Williams (1994) came to similar results in previous studies. The occlusion method has also been used to analyze anticipation in cricket (Müller & Abernethy, 2006; Müller, Abernethy, & Farrow, 2006), field hockey (Clatworthy, 1991) and fencing (Hagemann, Schorer, Canal-Bruland, Lotz, & Strauss, 2010).

Anticipation in karate has hardly been examined in sports. One of the first studies analyzing perception and action coupling in karate was by Scott, Williams, & Davids, (1993). In the first part of the study participants had to verbally identify the attacking body part and in the second part they had to respond with a physically appropriate movement. Experts performed better than novices in the second task, but not in the first. In another study Mori et al., (2002) examined novice and expert karate athletes’ anticipation using temporally occluded karate attacks presented on a video screen. The attacks were stopped at specific times before fully performed and the athletes had to verbally predict which part of their body would be hit. In comparison to the novices, the experts showed superior anticipatory skills in being able to predict the target area at early stages of the attack. Since only the temporal occlusion was used the point of time of the cues could be identified, but not the cues’ spatial locations.

All presented studies used two dimensional presentations as visual stimulation. It is assumed that the lack of depth information in these studies affected the participant’s perception and
anticipation skills and consequently the results’ ecological validity (Abernethy & Russell, 1987; Mori et al., 2002; Savelsbergh et al., 2002; Williams et al., 2002). Depth information is very important in sports in order to act and react appropriately. A two dimensional environment lacking depth information is not able to create a feeling of immersion which evokes realistic responses from athletes (Farrow & Abernethy, 2003).

One of the first studies using a three dimensional environment for sports was conducted by Bideau, Multon, Kulpa, Fradet, & Arnaldi (2004). The aim was to develop and evaluate the ecological validity of a virtual environment for sports. They were able to show that a virtual environment with animated virtual athletes, based on motion capture data, could be used for scientific research in sports. A virtual environment provides many advantages such as standardization, highly controllable environmental set-ups, repeatability and the possibility to manipulate human movements in a certain manner. Bideau, Kulpa, Vignais, Brault, Multon, & Craig (2010) carried out two experiments using a virtual environment to examine anticipation skills in rugby and handball: In the first experiment the novice and expert rugby players’ ability to perceive an attacker’s deceptive movements were analyzed. A HMD (head mounted display) was used to provide stereoscopic view of an attacker’s movements which was temporally occluded. The rugby players had to predict the attacker’s movement direction at the end of each occluded scene by pressing a button. The results show that rugby experts have a better ability to predict an attacker’s movement direction, based on the attacker’s kinematic information. In the second experiment a spatially occluded virtual handball penalty throw, animated by motion capture data, was presented on a stereoscopic screen. The handball goalkeepers had to react physically to the virtual penalty throws as if intercepting the ball in reality. The throws were modified to provide three different sorts of information: the ball trajectory, the thrower’s movements and both together. The results show that the highest number of successful interceptions is achieved when seeing the thrower’s movements and the ball trajectory.

This last study points out the abilities and advantages of using virtual environments in sports and furthermore the possibility to examine anticipation skills in conditions close to reality. In order to use these advantages and to analyze anticipatory skills in karate Bandow, Witte, & Masik (2012) developed a virtual environment in a CAVE. To provide realistic movements the virtual attacker was animated by motion capture data. The virtual environment was evaluated positively in regards to realism and immersion by karate athletes responding to karate attacks as well as by non-karate athletes viewing the attacks and answering a questionnaire (Bandow, Stucke, Trebeljahr, Masik, & Witte, 2012; Witte, Emmermacher, Bandow, & Masik, 2012). In order to compare the effects of a two dimensional and three dimensional virtual environment on expert karate athletes, one aim of this study is to compare the athlete’s responses towards occluded attacks in each environment. The other aim of this study is to identify the relevant anticipatory cues of the attack.

**Methods**

**Defining the temporal and spatial occlusions**

To analyze differences between the expert karate athletes’ responses in front of a two dimensional video screen (2D) and in a three dimensional environment (3D) the karate technique Gyaku-Zuki was chosen. The Gyaku-Zuki is the most often used technique in competitions and is characterized through its fastness and surprise effect (Figure 8).
Figure 8: The karate technique Gyaku-Zuki is accomplished by punching the opposite arm straight forward towards the opponent’s body. In detail: Stable stance. Rotation of the hip and shoulders. Beginning of stretching the back leg. Shifting the center of gravity forward. Moving the arm forward. Stretching back leg and punching arm forward until fully stretched, center of gravity is on the front leg.

To define the specifics of the temporal and spatial occlusion, a movement analysis of the Gyaku-Zuki was conducted by a karate expert athlete. Although the movement is performed slightly differently by each athlete, key movement characteristics can be defined. Based on these, three phases for the temporal occlusion were defined (Table 3).

Table 3: Phases of temporal occlusion based on visible movement characteristics.

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<td>• big step forward with the front leg</td>
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For the spatial occlusion the following body parts were chosen: *hip, punching arm, front leg.*

In order to define the time and the location of the anticipatory cues the temporal and spatial occlusions were combined into nine sequences (3 temporal x 3 spatial occlusions).

**Development of two and three dimensional stimulus footage**

The two dimensional stimulus footage was created by video recording of a female karate athlete who had international competition experience with an analogue video camera (Sony HDR FX7; resolution: 1080p) at a distance of 10 meters while performing the Gyaku-Zuki.

The video was transferred and digitized with Adobe Premiere Pro CS4 (Adobe Systems, San Jose, California, USA) without loss of quality. The spatial occlusions were created by replacing the hip, punching arm and front leg by each frame with the background using Adobe After Effects CS4 (Adobe Systems, San Jose, California, USA). The temporal occluded sequences were created from the already spatially occluded sequences by cutting the video.
when each phase ended. To avoid that the athletes only responded at the end of the presentation, the last 800-1000 ms of each phase was rewinded and attached to the end of each phase (Figure 9).

![Figure 9: Shows the last frame of the Gyaku-Zuki in phase 1 (A), phase 2 (B) and phase 3 (C) of the video presentation before the rewind.](image)

The attacker’s movements for the virtual three dimensional environment was created by capturing the same female performing the attack with the VICON Tracker motion capture system (Oxford Metrics, Oxford, UK). The recorded motion capture data were imported through a specific plug-in into the software Review3D which was developed by the Fraunhofer Institute for Factory Operation and Automation Magdeburg. This software allows adjusting the three dimensional karate model to the motion capture system’s model segments for the animation. The spatial occlusion is achieved by turning the model’s body segments invisible during the presentation. The duration of the presentation was predefined through an editable timer value, which allowed the exact presentation of each phase in combination with defined occluded body limbs.

The 2D and 3D virtual footage was presented in a special ordered sequence. The results of a pre-test from Zerbe, Kirbach, Bandow, Emmermacher, & Witte (2013) revealed an influence of presenting all phases in a random order, e.g. showing a phase 3 sequence before a phase 1 sequence, so that an order was defined where phase 1 sequences were shown first, then phase 2 and finally phase 3 sequences, but within one phase in random order. The analysis of the athlete’s anticipation skills to the Gyaku-Zuki was only one of four techniques performed by two attackers that are presented in this paper. Overall, the participants had to respond to 79 different sequences that were repeated three times, resulting in 237 sequences which the participants had to respond to. As in a normal round in a karate competition the sequences were presented in blocks over 2 – 3 minutes.

**Participants and experimental procedure**

Five male expert karate athletes with experience in national and international competitions (15.4(±1.67) years of age) responded physically to 27 sequences of the Gyaku-Zuki in each environment. They were instructed not to attack without a reason or to start an attack, only to respond when they thought an attack was carried out. The type of response was not predefined, but they were instructed to respond in order to gain a point as if in a real competition.

The procedure for all participants was the same. First, they were tested for stereovision with the Stereo Fly Test (Stereo Optical Co., Inc., Chicago, USA). This test measures whether the eyes can perceive objects at different distances presented on a slide. The participants had to
wear polarized spectacles and identify which objects on the slide were pointing towards them. All participants had normal spatial vision of at least 40-60 seconds of angle of stereopsis. Immediately after the test they had time for a warm-up. So as to familiarize themselves with the virtual environment and the stereovision, the participants underwent 15-30 trial attacks. The athletes then had to respond to all 16 blocks, each including 15 attacks, with 3-5 minutes breaks in between. The test in front of the two dimensional video screen was performed in the same manner.

The athlete’s physical responses were recorded with two high speed cameras (Optronis GmbH, Kehl, Germany; model CR600x2; 200Hz; 900x900 px) simultaneously. One camera captured the athletes from the front, the other from behind at a left angle. The video footage was viewed by two independent raters who assessed and classified the participant’s responses into two categories: correct and incorrect responses. A response was classified as correct, when the first visible physical response was within a range of 100 ms after the begin and 200 ms after the end of the visible attack.

The repeatability was verified using the Cochran’s Q-Test. The Wilcoxon test was applied to analyze the differences in responses between the 2D and 3D environment statistically.

The experiment was carried out under the ethical guidelines of the academic institution and the participants’ consent.

Results

The results of the Cochran’s Q-Test show no significant differences (p>.05) between the first, second or third response to the same occluded sequences, proving a repeatability of the responses to the stimuli.

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<th>h 1</th>
<th>h 2</th>
<th>h 3</th>
<th>fl 1</th>
<th>fl 2</th>
<th>fl 3</th>
<th>pa 1</th>
<th>pa 2</th>
<th>pa 3</th>
</tr>
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<tbody>
<tr>
<td>Z-value</td>
<td>-.816</td>
<td>-2.070</td>
<td>-.577</td>
<td>.000</td>
<td>-1.00</td>
<td>-.707</td>
<td>-.447</td>
<td>-.921</td>
<td>-1.89</td>
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<tr>
<td>p-value</td>
<td>.414</td>
<td>.038</td>
<td>*</td>
<td>.564</td>
<td>1.00</td>
<td>.317</td>
<td>.480</td>
<td>.655</td>
<td>.357</td>
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The participant’s responses differ significantly (Z=-2.325, p=.003) between the 2D environment (31% correct responses) and the 3D virtual environment (49% correct responses). A pairwise comparison of correct responses between each sequence of the 2D and 3D environment show significant differences only for h 2 (Z=-2.07, p=.038) as well as a tendency for pa 3 (Z=1.89, p=.059) (Table 4). The percentage of correct responses in each environment from all participants for each occluded sequence is shown in Figure 10.
The number of correct responses to each attack presented in the 2D environment is lower than in the 3D environment. The athletes responded 33(±21)% correctly to sequences in phase 1 with occluded front leg as well as hip and only responded 20(±27)% correctly to attacks with occluded punching arm in the 2D environment. The number of correct responses to attacks presenting the first two phases are below those of phase 1 for the occluded front leg (27±25%) and hip (27±33%), but not for the punching arm, where the best results in the 2D environment are achieved (47±34%). The results for phase 3 sequences show best results for occluded front leg (40±25%) and hip (33±21%), but not for occluded punching arm (20±16%).

The athlete’s responses in the 3D environment provide a more differentiated structure. The athletes responded worst to the attacks when only presenting phase 1 with occluded front leg (33±0%) and punching arm (27±25%), except with occluded hip (47±16%). The highest number of correct responses were to attacks presenting phase 1 and 2 sequences with occluded hip (73±25%) and punching arm (67±30%), except for the occluded front leg (40±25%). The percentage of correct responses decreased at the presentation of all three phases (phase 3) with the occluded hip (40±33%) and punching arm (60±25%), except for occluded front leg (53±27%) where the highest number of correct responses occurred.

Discussion

The results of the Wilcoxon test for all responses show a significantly higher number of correct responses in the virtual environment compared to those in the video based environment. This applies for each environment and all sequences. Although a detailed analyses of the results for each sequence for the 2D and 3D environment show a significant difference only for hip 2, the differences of correct reactions in each environment is apparent. The lack of more significant differences between each sequence is due to the low number of data (5 athletes with maximum three correct responses per sequence). The significantly higher number of correct responses towards all sequences is most probably due to the different environments, which differ from each other in the perception in depth, feeling of presence, immersion and the resulting possible fear of physical contact. These factors are typical for real-world environments and it may be
assumed that the virtual environment offers a more realistic experimental setup than a 2D video based environment. These results confirm outcomes of previous studies from Bandow, Emmermacher, Stucke, Masik, & Witte (2013) and Bideau et al. (2010), who evaluated virtual environments in regard to realism and possible usage for studying anticipation scenarios in sports. It can be concluded that this test environment is suitable for evoking realistic responses or decisions, while cognitive processes such as anticipation are very sensitive to environmental conditions (Bideau et al., 2004).

The results of the Wilcoxon test for the responses to each sequence in the 2D and 3D environment show no significant differences. It is assumed that the failure of significance is based on the level of expertise and the presentation of the same attack with only small variations caused by the temporal and spatial occlusion. A significant difference in response is not expected, but there are tendencies which are analyzed.

The results of the 2D environment show no clear tendency in regard to the presented information and the number of correct responses. The responses to phase 1 sequences with occluded front leg and hip are more often correct compared to phase 2 sequences. The only exception showing the lowest number of correct responses in phase 1 is the occluded punching arm, which increases clearly in phase 2 and decreases again in phase 3. Contrary to responses in the 3D environment, the responses to occluded front leg and hip improve slightly in phase 3, which may be because more information is presented. The results of the 2D environment do not provide the same tendencies, as the results from the 3D environment and other studies: in 3D environments the response accuracy increases with an increase of information (Blake & Shiffrar 2013; Jones & Miles, 1978; Williams, 2004). It can be shown that the results of the 3D environment are more reliable than those of the 2D environment, as the 3D environment is able to evoke realistic responses better. The results also show that the number of correct responses in the 3D environment is lowest at the presentation of phase 1 sequences. The only exception is to the sequence with the occluded hip, which will be discussed later. In general it was expected that the participants would respond worst to phase 1 sequences, because here the least information of the attack was provided. The increase of correct responses to phase 2 sequences in comparison to phase 1 sequences was expected and confirms an improvement of correct responses with increasing information. The decrease of correct responses to phase 3 sequences with occluded hip and punching arm, which is supposed to provide most information, is therefore unexpected. It is assumed that expert athletes do not respond that often correctly to phase 3 sequences, because they know that in such situations it is normally impossible to achieve a point. This phenomenon has also been discovered in a study by Farrow and Abernethy (2001). The only improvement in response accuracy is with occluded front leg, which is discussed in relation to spatial occlusion.

In summary the results of the 3D environment show that there is a link between response accuracy and the number of presented information. The expert karate athletes are able to recognize the first visible cues in phase 1, which allows enough time for an appropriate response. Their anticipatory performance increases when receiving additional information in phase 2 and decreases in phase 3, which is supposedly based on the fact that the information experts need for anticipating and responding appropriately lie within the first two phases of an attack. These findings match the results from Blake & Shiffrar (2013), Jones & Miles (1978) and Williams (2004) that experts can perceive and use information in initial sequences of an attack for anticipation. The results of the 2D environment do not show any of the mentioned tendencies, therefore it is assumed that the lack of depth information and immersion leads to an unrealistic environment which influences the behavior.
In regard to the results to the spatially occluded sequences, the locations of the anticipatory cues change over time (or phases), especially in the 3D environment. This can be shown in Figure 10, where the difference in percentage of correct responses to one spatially occluded body part changes over each phase. Analyzing the responses to the different spatial occlusions along with the movement characteristics of each phase, the first anticipatory cues can be identified. The number of correct responses in phase 1 to occluded front leg is the same in both environments, as well as the worst response accuracy to occluded punching arm in this phase. The low number of correct responses towards the occluded punching arm and front leg of phase 1 can be explained by withholding the following information: taking the punching arm to the body and a bigger step forward with the front leg. The occlusion of the hip in phase 1 shows a low number of correct responses too, but does not cover information of high importance in the 3D environment. It seems that the occlusion of the hip in the 2D environment could be caused by the lack of depth information which covers up the beginning lateral rotation of the torso. It is also assumed that the exposure of the back leg contains important cues and gives enough information as supplement for the spatial occlusions. Looking at the responses to the spatial occlusion of phase 2 sequences in the 3D environment, it seems that only the occlusion of the front leg contains important cues, which is the beginning of lifting the front leg. This movement achieves a reduction of the distance between the attacker and the participant, which is a crucial action in karate. The occlusions of the hip and punching arm mask the movements positioning of the punching arm and the lateral rotation of the torso. While they are already in progress at the beginning of phase 2 they are predictable and expected and therefore not used as anticipatory cues. This behavior could also be seen in other studies, which observed experts ignoring redundant information (Farrow & Abernethy, 2001). In contrary the results in the 2D environment in regard to the occluded hip may underlie the same issue as in phase 1, lack of depth information with covering up the body rotation partially. Nevertheless, the response accuracy to occluded punching arm and front leg mirrors the results in the 3D environment, that the punching arm is less important than the front leg in this phase of the attack.

Table 5: Marked movement characteristics which are assumed to be important cues during the attack.

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In phase 3 the number of correct responses decreases unexpectedly in the 3D environment, except for the occluded front leg, which shows the highest number of correct responses. The same is detected in the 2D environment. This occurrence can be explained through the forward movement being already in progress, since phase 2 only provides redundant information that is not taken into account for anticipation. The number of correct responses to the sequences with occluded punching arm is less, compared to those of phase 2, but the highest compared to the
other spatial occlusions in phase 3. It can be concluded that the importance of the punching arm is most significant at the beginning of the attack because the movement that follows is predictable. Overall, it can be shown that the whole body movement plays an important role in anticipation and should therefore be taken into account, too, due to the occlusion of the hip masking the end of the lateral rotation of the torso, which results in a low number of correct responses, at least in the 3D environment.

It could be shown that the participants are capable in responding to all sequences, independent to how much information of the attack is given. This confirms the fact that not only isolated cues in certain body parts, but also their relation to each other provides sufficient information about an upcoming movement (Goulet, 1989; Jackson, 2007; Shim, Carlton, Chow, & Chae, 2005).

The changes of cues during the attack show the importance of parts of a movement dependent on the time or movement phases.

Conclusion

This study shows that using a virtual environment for analyzing anticipation in sports can be an appropriate option especially when compared to a video based 2D environment. The higher number of correct responses in the virtual environment is based on the advantages of a 2D to a 3D representation. It could be demonstrated that the additional information about depth and immersion has an influence on the participant’s behavior. While these aspects are important factors in real-life, it can be assumed that the virtual environment evokes more realistic responses by a person and is therefore more appropriate for studies of anticipation, especially in sports.

Furthermore, it could be shown that the combination of the temporal and spatial occlusion technique allows a more specific determination of relevant cues for an attack. The cues can be located and sorted to the defined phases as well as to their location. Based on this, the changes in cues during an attack or a movement are definable.

Analyzing the participant’s responses towards each occluded sequence certain tendencies can be discovered. The results show that there are different cues during the initial phase of an attack which can be detected by the expert karate athletes. This knowledge can be used to create a training scheme for better perception and anticipation. The success of such a training has then to be evaluated. This study could also be undertaken with novice karate athletes to analyze, whether they are able to detect the same cues. This can give further knowledge about the differences of expertise in karate and help to improve training schemes.

In order to achieve more detailed information about the cues, further studies with more isolated and also combined spatial occlusions should be implemented. The additional use of eye-tracking-systems can also foster these analyses extremely.

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References


