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Usage of Virtual Reality Technology to Study Reactions in Karate-Kumite

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Abstract. The aim of this paper is the presentation of a measurement station to determine the anticipation skills in combat sports. Therefore technologies of virtual reality (VR) are being used which create sports specific stimuli. An advantage of this measurement station is that stimuli are visually three dimensional and can be created standardized. Whereas a high immersion as well as a realistic three dimensional environment is a crucial requirement for a good VR the CAVE (Cave Automatic Virtual Environment) was selected. The participant's reaction times of nine karate attacks presented in the CAVE, in front of a computer screen and a two dimensional screen were examined. The development of the virtual karate attacker was performed by creating a virtual character animated with motion capture data (VICON) from real karate attacks. It was determined that the participant's reactions were more similar to reality than to reactions to the two dimensional screen. Based on these results it can be concluded that it is possible to perform tests which inherit temporal and special occlusion tasks as well as the integration of an eye-tracking-system in order to identify early and late cues. It is expected to be a helpful tool to examine the anticipation of athletes in a realistic way.

Keywords: Virtual reality, anticipation, visual search strategy, combat sports, karate, cave

1. Introduction

In sports science anticipation is understood as the presumption of an action, an action effect or outer dynamic changing of environmental conditions [1]. Through anticipation the athlete reacts adequately to movements of his opponents [2]. Anticipation is not only crucial in combat sports but also in sports games. A handball goal keeper for example has to anticipate the ball's flight trajectory correctly in order to react appropriately. There have been examinations of eye movements and visual search strategies by Roth and Schorer [3]. To determine which visual information is being used at which point of time, temporal and special occlusion tasks were performed ([4], [5]). The relevance of early and late cues for anticipation was detected by Froese & Plessner [6]. Nevertheless, the interpretations of the results are not clear due to the fact that the term reaction time cannot be defined clearly. Reason therefore is the identification of the proper cue and its point of time. However the term reaction time will be used in this paper.

Successful performances in combat sports as well as in sports games require not only efficient and correctly executed techniques but also a high level of perceptional skills. There are two forms of stimuli which influence perception: general, simple stimuli (e. g. light signals) and sports specific stimuli. To examine sports specific stimuli standardized conditions are required in order to control the variation of influencing factors. Commonly video presentations or presentations on a life-size screen where used: Schorer [7] analyzed a handball goal keeper's behavior and eye movement during a 7-meter throw. Savelsbergh, Williams, van der Kamp & Ward [8] used a video measurement station to examine visual search strategies of soccer goal keepers. A major problem in the usage of video measurement stations is the lack of the third dimension, which is an important factor in combat sports for the purpose of estimating the opponent's distance. A study verifies the dependence of the distance to the opponent and the hit frequency [9]. Bideau, Multon, Fradet, Arnaldi & Delamarche [10] present an alternative research tool to video measurement

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stations: VR technologies. They create a standardized and controlled test environment to analyze the behavior of a handball goal keeper who tries to catch balls from a virtual handball player by means of VR technology. Commonly VR technology is being used more as simulation and training tool than for research in anticipation [11].

Researches of anticipation in combat sports under realistic conditions have a great importance because only little knowledge about early and late cues exists. Hermann, Scholz, Vieten & Kohloeffel [12] report about different reaction times in dependence on the target at the body for Taekwondo. Tanaka, K., Hasegawa, Kataoka, & Katz [13] studied the zuki (jap. punch) reaction of karatekas to several typical basic techniques: jumping with defense posture, forward steps, backward steps and feint forward steps by means of a virtual karate system. They found out that given information about self-position and postures don't influence the reaction time of experts. In contrast, when the novices get self-information their reaction time was significantly shorter.

This underlines the importance of the measurement station in regards to the determination of reaction times. Mori, Ohtani & Imanaka [14] examined the reaction times related to general and sports specific stimuli by means of a two dimensional computer screen measurement station. The results showed shorter reactions times for the experts for both stimuli compared to the novice's reactions times.

To train perception associated with tactical training only sports specific videos have been used. Cañal-Bruland, Hagemann & Strauß [15] showed that this sort of video training improved the athlete's reaction times without increasing the error rate. Moreover it is possible to track visual search strategies with helmet cameras [16]. A difference between novices and experts in regards to fixation and duration time of fixation was determined. Furthermore Savelsbergh, Williams, van der Kamp & Ward [8] examined goal keeper's estimation skills of soccer shots on a goal by means of a life size video screen and a joystick to show were the ball would go.

Whereas a three dimensional presentation of an opponent without taking the distance into account is not sufficient, three dimensional video presentations do not meet the athlete's requirements of feeling to be in a real environment. To comply with these requirements Tanaka [17] suggests presenting the athlete's movements three dimensionally as well as the feedback of the reactions by means of Mixed Reality (MR) technology. Therefore a virtual karate system based on the karate game "Kumite" [18] was developed where the athlete wears a Head-Mounted-Display (HMD) in which the virtual opponent is being presented. Referring to [17] the athlete's perception could be improved.

To study anticipation by means of VR several requirements have to be met, especially a high level of immersion. Sherman & Craig [19] define four elements which are essential for VR: virtual world, immersion, sensory feedback and interaction. Therefore it is crucial that the participant accepts the virtual world as the real world (s. [20], pp.3ff).

Based on these facts following requirements for a VR measurement station for anticipation can be defined:

stereoscopic presentation

freedom of movement of the participant

tracking of the head movement

virtual environment which surrounds the participant as far as possible

The aim of this paper is the presentation of a measurement station based on VR technology in order to analyze anticipation in combat sports. Furthermore an examination and comparison of the athlete's reaction times related to different karate attacks and different presentation scenarios is being accomplished: VR measurement station, PC-test with video in real time and in slow-motion, video presentation in life size on a screen and in reality.

2. Materials and Methods

2.1. VR measuring station: CAVE

To meet the above mentioned requirements for a VR based measurement station for anticipation the CAVE was selected as test environment. The CAVE provides a high level of immersion which is important in sports. The CAVE has four projection screens each 2,30m x 2,30m of size which allows enough space for the participant to move as well as an integrated tracking system (ART) which tracks the head and adjust the virtual environment to the participant's position in the CAVE.

The development of the virtual karate was based on the creation of a computer graphics model by means of 3ds max (Autodesk) and motion captured data of real attacks (VICON, Plug-in-Gait-Model). The following steps had to be accomplished in order to have an motion capture animated virtual karate attacker in a virtual environment: a) development of a 3-dimentional model (skin), b) creation of a skeleton which fits onto the model (Bibed), c) development of key-frame based animation (motion capture data), d) export and fusion of all components: skeleton, 3-dimensional model and animation data in to the Cal3D (open source character animation library) format. Finally the model was transferred into the VRAuthor (self developed software of the Fraunhofer Institute of Factory Operation and Automation IFF), an author software that is based on OpenGL and the OpenScene Graph in order to display models in a virtual environment. The VRAuthor offers the opportunity of embedding plug-in modules for specific functionalities, respectively.

2.2. PC measuring system (PCR and PCSM)

Furthermore software was developed by [21] to determine the reaction time of karate attacks displayed on a computer screen, once in slow-motion and once in real time. The participant's task was to press a key when he thought being able to identify the technique of the attack. The optimal point of time of being able to identify the technique was determined by an expert.

2.3. Life-size video on a screen (2D)

In this test the attacks were displayed in life-size onto a screen. The participants, who were standing in front of the screen, as well as the displayed attacker, were recorded by video cameras in order to determine the right point of time of the beginning of the attack and the participant's reaction. Figure 1 shows the used scenarios (without PC-Test).

Figure 1: Experimental scenarios under real condition (Real), Life-size video on a screen (2D) and VR-measuring station CAVE

2.4. Techniques, subjects, assessments

Table 1 shows the selected karate attacks as well as their abbreviations for the test. Each attack was recorded once by video (for 2D) and once by an infrared-based motion capturing system (VICON) (for 3D) each of a male and a female karate. The same video was used for the PC test as well as for the 2D-scenario. To have the identical attacks the same karatekas performed these in the real test environment. However to keep the learning effect low the sequence of the attacks was different for every scenario.

There were 4 male (SR, PH, RH; MB) and 2 female (TB, SB) participants with national and international experiences in competitions. The participant's (Ø22±7 years) task was to react as fast as possible with a Gyaku-Zuki (jap. reverse punch) against the attacks. The reactions of all participants in every scenario were recorded with the aid of a high-speed-camera (200Hz) and were analyzed afterwards by an expert. The analysis is based on the point of time of the first visible reaction of the participant and was rated by the following scale: 3: proper point of time, 2: acceptable point of time, 1: almost too late, 0: too late, -1: far too late or no reaction.

Table 1: Selected karate attacks with explanations and their abbreviations Jodan – target: upper area (head and neck), Chudan - target: middle area (trunk)

Mawashi-Geri (Roundhouse kick) with front leg, Jodan	T1
Gyaku-Zuki (reverse punch), left	T2
Gyaku-Zuki / Mawashi-Geri (with rear leg)	T3
Gyaku-Zuki (reverse punch), right	T4
Gyaku-Zuki (reverse punch), overrun	T5
Mawashi-Geri (Roundhouse kick) with rear leg, Shudan	T6
Kizami-Zuki (snapping the leading fist forward), left	T7
Gyaku-Zuki / Mawashi (with front leg), Jodan	T8
Kizami –Zuki (snapping the leading fist forward) / Gyaku-Zuki (reverse punch),	T9

3. Results

The PC-test examined, if an early recognition of an attack was possible based on video presentations. Fig. 2 shows the results of two participants.

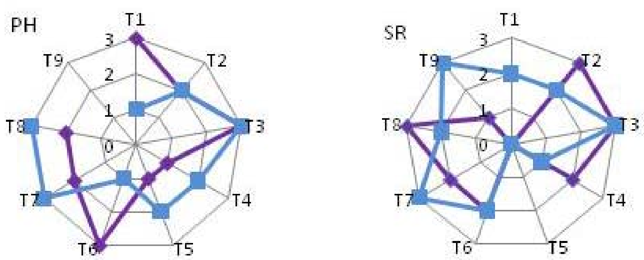

Figure 2: Assessments of reaction time in relation to techniques T1…T9 for PC-Test, demonstrated on results of two male subjects PH and SR. Light blue: slow-motion (PCSM), purple: real time (PCR)

In general the participants are not able to detect the reactions early enough, neither in real time nor in slow motion. Furthermore the technique of the attack plays a big role for the point of time of the identification [21]. Previous results, that the Gyaku-Zuki including the different accomplishments was recognized to late, could be certified. A comparison of the mean values of the reaction times for the slow motion test and the real time test show that the ones of the slow-motion were significantly better (Wilcoxon, $p<0.17$).

The following tests shall show which similarities and differences can be found between the test environments.

First decision to make was, if to use the real absolute reaction times or the rating results by the expert. To meet the requirements of comparability of the PC-test and the other scenarios, the usage of the results of the expert rating were used for the analysis. An analysis of correlation of the absolute reaction times and the expert ratings show a slightly, not significantly negative coefficient of correlation (Kendall). The explanation for the big difference lies in the big differences in point of times of the movements of the arm techniques (T2, T4, T7), leg techniques (T1, T6) as well as in their combination techniques (T3, T5, T8, T9).

Figure 3 shows the estimated reaction times for all test scenarios once for the participant's (PH, SR) who were shown in Fig. 2 and for MB who has less years of training.

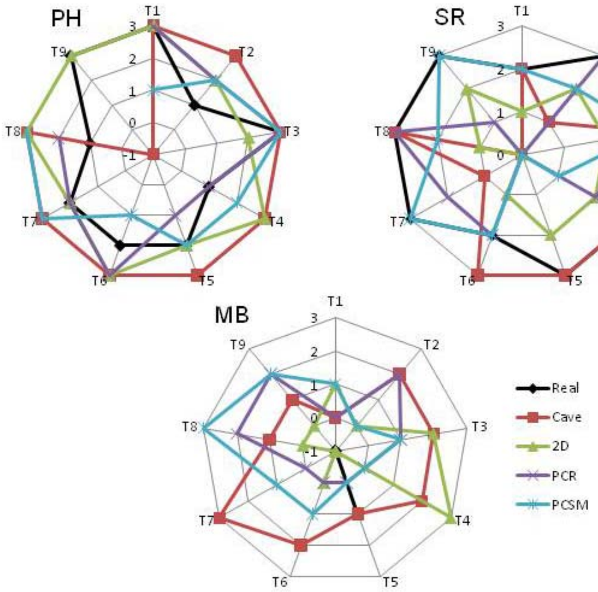

Figure 3: Assessments of reaction time in relation to techniques T1…T9 for all experimental scenarios, demonstrated on results of three male subjects: PH, SR and MB

The results of the expert rating in regards to the reaction times reflect the big differences of the participant's performance level. There are also big differences in the single techniques. All participants coped well with the 3D test scenario (CAVE) except participant TB. Participants SR and PH in comparison had very good reaction times and appropriate reactions in this scenario. Against expectations most participants did not have better and more appropriate reaction times at the PC-test with slow-motion than at the PC-test in real time. Nevertheless there is no attack technique which was anticipated very fast by any participant.

Figure 4 shows the amount of the best expert rating (+3) of the reaction times in each test scenario. Overall it can be said that the highest amount of the best rating (+3) was accomplished in the 3D-scenario (CAVE). After that the amount of best results can be found in the real-scenario, PCSM, PCR and in the end in the 2D-scenario. The best rate of +3 was for all participants' worst in the 2D-scenario except for PH. Based on these results it can be concluded that the attacks were better anticipated in the 3D-scenario than in the 2D-scenario. In reference to the real scenario the better results can be interpreted that the participant feels more in reality in the 3D-scenario and hence reacts faster than in reality because he is afraid of hits or kicks.

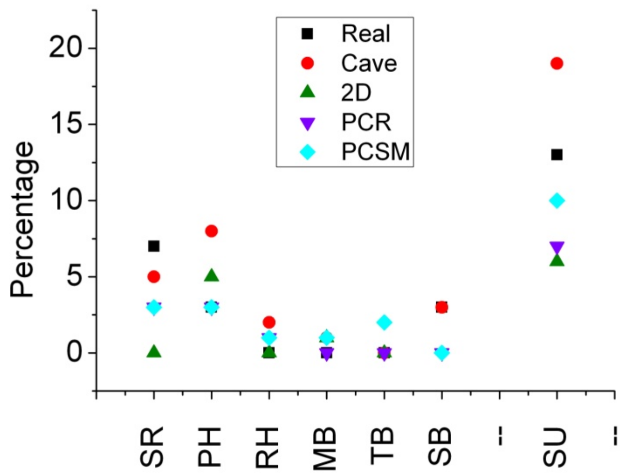

Figure 4: Percentage of the assessment "+3" over all attacks for each subject and for all subjects (SU)

Next question to be answered is how stable the reaction techniques to the attacks are based on the task that the participants should only react with a Gyaku-Zuki. Nevertheless the test in the 3D-scenario was repeated (Cave1 and Cave2). Figure 5 shows the reaction technique of two participants of the same attack in all test scenarios. It can be seen that they did not react with the predetermined technique Gyaku-Zuki in every case.

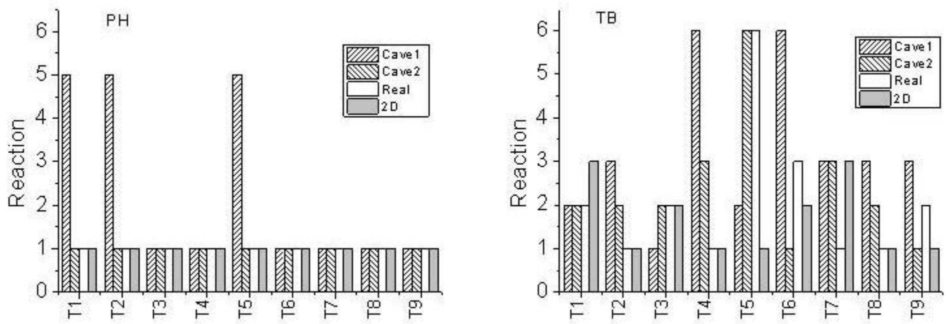

Figure 5: Reaction techniques in regards to the attacks T1….T9 for the subjects PH and TB. 1 – direct counter with Gyaku-Zuki, 2 – evasion leftwards + Gyaku-Zuki, 3 – evasion rightwards + Gyaku-Zuki, 4 – Gyaku-Zuki + other karate technique, 5 – other karate technique, 6 – no reaction or completely inadequate

Of big interest is the equal amount of reactions between the test and re-test. Summed up over all participants there is conformity of 49% and over the most skilled (SR, PH and RH) of 67%.

Fig. 6 shows the percentage of proportion if the reaction technique 1 (direct Gyaku-Zuki) for each scenario. According to expectation the more skilled athletes react more often with the direct Gyaku-Zuki. It is noticeable that this technique is less used in the real scenario but most in the 2D-scenario. This may be explained by the easier conditions in the 2D-scenario, whereas here the participant does not have to fear a hit, contrary to reality. The 3-D-scenario CAVE alternatively lies in between: on the one side the reaction technique 1 was used more often compared to the real scenario but on the other side the artificial conditions in the CAVE seem to reflect reality better than the 2D-scenario. Despite the small amount of participants (n=6) there can be a difference found in between the athletes with many years of training and athletes with only few years of training. Further tests should verify this.

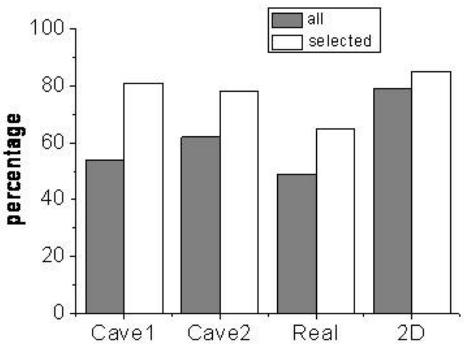

Figure 7: Percentage of reaction technique direct Gyaku-Zuki in the several experimental scenarios for all subjects and selected subjects (SR, PH, and RH)

4. Discussion

It can be assumed that the reactions to attacks in combat sports can be estimated more realistically by means of sports specific stimuli training rather than with simple visual stimuli. For this reason a measurement station (CAVE) was developed based on VR-technologies. Furthermore the reactions to attacks shown in the CAVE were compared to those performed or showed in other test scenarios: video presentation at a monitor (PC-Test), 2-dimensional video projection in life-size and real conditions against a real attacker.

At first it should be noted that the PC-test differs fundamentally in comparison to the other test scenarios, whereas no karate specific reaction is recalled but only a button has to be pressed. In accordance to previous results from [21] who's examination was based on a similar design show that the attack techniques are recognized earlier in slow-motion condition (PCSM) than in real time condition (PCR). Furthermore it can be assumed that the type of reaction is being influenced by the type of attack. This can be based on various reasons: duration of the attack, individual execution of the attack, frequency of performance of the attack in training and competition. In terms of practical training it is recommended to use the slow-motion condition in order to sensitize the athlete to the specific stimuli related to the attack.

Figure 5 illustrates how individually the participants react to the attacks in the test scenarios. The total of the expert rating (SU) shows that the participants had the most optimal reaction time (+3) in the CAVE and the worst in the 2-dimensional scenario. This means that the video presentation of the attacker in life-size on a screen is not to be realistic enough. Results in regards to perception and anticipation which are based on 2-dimensional stimuli should be seen critical. At the same time it should be taken in to consideration that only through 3-dimensional video technology and VR-technology a near to reality picture of real conditions can be created. Thereby it is not enough to display the opponent and the distance between the participant and the opponent 3-dimensionally but also to create a deep immersion. This basically means that the participant has to accept the virtual environment as the real environment.

A deficiency of this study is clearly the usage of only visual stimuli. According to the participants a haptic feedback was missing. As a consequence the fear of being hit or kicked missed and the reaction was started earlier, compared to the attacks in reality. This can be a reason for the very short reaction times. Another reason can be that earlier cues were recognized which lay before the actual beginning of the attack.

Further reasons can be found in the virtual attacker which, at that time, was at the technological level of not being ‘intelligent’, which means that he did not react to the participants movements. The development of an interactive attacker can be seen as a goal for the future. An example can be given from [22] who created an intelligent virtual table tennis opponent.

The presented measurement station ‘CAVE’ based on VR-technology is in general suitable to do research in regards to eye movements with an eye-tracking-system ([23], [24], [25], [26]). Thus it would be possible to detect early and late cues in karate sports based on temporal and special occlusion tasks ([27] for tennis serve).

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