Katharina Petri, Melina Droste & Kerstin Witte

Analysis of anticipatory cues in karate kumite using an in-situ-study

Abstract

Anticipatory cues, and how they are affected by gender, expertise and age, are not identified sufficiently in karate kumite. In an in-situ study, 24 karate athletes reacted to attacks of a real opponent and we analyzed the cues by identification of the first time of the reaction and subtraction of individual reaction times from that point to examine the relevant movement stage of the attack using video analysis (100 Hz). We divided the attacks into four movement stages. In our sample, we compared men with women and athletes of international with national competition experience, and we related the age to the relevant movement stage. We found that regardless of gender, expertise level or age, the arm attacks Gyaku-Zuki, Gyaku-Zuki overrun and Kizami-Zuki were most often recognized in movement stage 1 (early steps) and 2 (reduction of interpersonal distance). These movement stages seem to serve as universal cues for all analyzed attack types.

Keywords

anticipation, interpersonal distance, attack recognition, reaction, cues

Contact

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1 Introduction

Anticipation is an essential factor in daily life situations and in many sports, such as ball sports or martial arts. In karate kumite, it is important to forecast the opponents' or teammates' intentions to get more time for the own motor response. That is crucial, because opponent's actions are very fast in karate, and thus, the responding athlete has not enough time for adequate response in case of a too late reaction (beginning of the reaction when the attack is almost finished). For details of perceptual-cognitive skills in combat sports athletes, we refer to Russo and Ottoboni (2019). In previous studies, it was shown that anticipation can be enhanced through training with video material (e.g. Milazzo, Farrow & Fournier, 2014, Müller et al., 2017) and virtual reality (e.g. Petri, Bandow, Masik & Witte, 2019, Petri, Masik, Danneberg, Emmermacher & Witte, 2018). Nevertheless, more studies are required to analyze the transfer from labor testing and labor training into the field. It should further be examined how such training, as well as instructions and feedback, should be provided to ensure positive transfer. Finally, it is further not clarified if any learning effects last over longer period (Loffing & Cañal-Bruland, 2017, Morris-Binelli & Müller, 2017).

Future actions can be perceived based on kinematic data, thus information in the humans' movements, but also due to situational probability information and situation specific and non-specific contextual information, such as the position of athletes in the field, current score, knowledge about athletes' preferences and habituation to movements of opponents and teammates (Dicks, Button, Davids, Chow & van der Kamp, 2017, Mann, Schaefers & Cañal-Bruland, 2014), as well as due to ball flight information (Loffing & Cañal-Bruland, 2017, Runswick, Roca, Williams & McRobert, 2018). Besides the visual expertise for adequate perception, motor experiences play an important role in anticipation [13]. For review of anticipation see Morris-Binelli and Müller (2017), as well as Müller and Abernethy (2012). Furthermore, pattern recognition is important for anticipation. Rather than observing specific details, athletes perceive general patterns in the movements of other athletes, especially opponents, and compare them automatically with previous situations due to their comprehensive expertise. Future actions can be recognized very early based on movement (changes) and pattern recall (Abernethy, Zawi & Jackson, 2008), Loffing & Cañal-Bruland, 2017) but also due to posture and emotions (e.g. Contiero, Kosiewicz & Baker, 2018).

Peripheral vision plays a major role in perception and anticipation. In several sports, also in karate, athletes fixate a visual anchor (often the head or the upper body in karate, or a point between several athletes and the ball in team sports) while perceiving relevant signals in the periphery due to movement or velocity (changes) (Williams & Elliott, 1999). Petri, Bandow, Salb and Witte (2018) confirmed these findings in an in-situ study with karate athletes and underlined the importance of kinematic information from the attacker's motion. Although the athletes fix the head of the opponent, the information available was not beneficial to correct anticipation. The opposite was the case: with occlusions of facial expressions and eye movements of the attacker, responding karate athletes significantly improved their attack recognition performance and response behavior (Petri, Bandow, Salb & Witte, 2018). The usage of kinematic information, as well as the knowledge about tactics and deceptive movements is crucial for the own advantage (Belling, Suss & Ward, 2015). Especially in martial arts, therefore also in karate, decisions have to be made under a large time pressure and incompleteness of all information. It does not make sense to perceive the whole upcoming attack because then, the remaining time for an appropriate response would be too short. Therefore, visual perception, attention and anticipation based on relevant (early) kinematic information are essential for early and correct decision-making and motor response in many sports (Afonso, Garganta & Mesquita, 2012).

It is well known that expert athletes outperform their lesser skilled counterparts both in small-sided games (1:1 situations in racquet sports and martial arts) and in large-sided games (team ball sports). Experts show faster and more accurate attack recognition and better response behavior than advanced athletes or novices due to their ability to perceive and use relevant signals correctly (Belling, Suss & Ward, 2015). However, the anticipatory signals, in which athletes perceive future actions, are still insufficiently investigated in many sports.

Anticipation can be investigated by using several methods: manipulations of the visual stimulus (e.g. occlusions, blur or point-light-displays) in video or virtual reality, eyetracking (where natural movement execution is often restricted to avoid artefacts in data recording), questionnaires (asking the athletes to which signals they responded, however, the majority of athletes is not aware of that knowledge), cognitive measures such as fMRT or EEG (Belling, Suss & Ward, 2015), and in-situ studies by use of reaction times (Petri et al., 2016). Unfortunately, there is a lack in measuring tools to analyze sports specific reaction times (Liu et al., 2018). Reaction time is defined as the time from the appearance of a stimulus until the first reaction to it (Cagri Cetin, Tasgin & Arslan, 2011). Many factors have an influence on reaction time, such as age, gender, fatigue, hand dominance, visual ability, nutrition, exercise, sport activities, and medical condition (Liu et al., 2018). Reaction times can be improved through training in real world settings (e.g. Milazzo, Farrow & Fournier, 2014) and virtual reality (Petri et al., 2019). However, the specific reaction times are not clear in many sports, also in karate kumite.

In karate, most techniques are performed on a straight trajectory and due to that direct way, they are very fast (Venkatraman, Manwar & Avanaki, 2019). Matsushita and Yamada (1998) used temporally occluded videos and found that expert karate athletes were able to recognize upcoming attacks correctly by the attacking body parts (arm and legs), as well as on other body parts. However, novices were only able to use the arms and the legs for attack recognition rather than to perceive and use the information on preparatory movements before the actual attack.

In ball sports, mainly end-effectors were found to be relevant for correct stroke prediction (Williams, Huys, Cañal-Bruland & Hagemann, 2008). van der Kamp, Dicks, Navia and Noel (2018) stated that rather than only one single relevant cue, the interplay of several cues located in the whole body are important for correct perception and anticipation and highlighted that perception might be an individual process. In tennis, it was found that experts use more global and more proximal signals (e.g. the head or the trunk) while novices use more local cues (e.g. the arm) (Williams, Huys, Cañal-Bruland & Hagemann, 2008). However, the authors noted that that idea of experts' global cue usage may not hold in other sports. Therefore, further studies are needed to analyze anticipatory cues in several ball sports and martial arts.

In a pilot study, Bandow (2016) analyzed cues in karate kumite using standardized and three-dimensional virtual reality and found the hip and the arms to be cues for perception of several arm and leg attacks. Petri et al. (2016) carried out an in-situ study and used the same method as Bandow (2016). First, the attack movements were divided into several movement stages. Second, the moment of the first response of the reacting karate athlete was detected. From that first reaction, 150 ms, as assumed reaction time based on Zaciorskij (1971), were subtracted to analyze in which movement stage the attack was perceived. It was shown that both the kind of attack in combination with the distance between both athletes were anticipatory cues. Furthermore, the attacks could be recognized even before the actual attack movement started (Petri et al., 2016).

The anticipatory cues to which athletes perceive attacks are still not clear in karate and the first results are not validated yet. Therefore, there is a further need to examine these primarily kinematic signals based on opponent's movements. Once these cues are identified, it would be possible to develop new training programs to sensitize athletes and coaches for the relevant signals to accelerate the learning process and improve information intake and processing, especially for young athletes. As was described earlier, expertise (especially visual expertise for efficient search behavior and motor expertise due to large training and competition experience) plays an important role in correct anticipation.

However, it is still unclear, if the factors gender and age have an influence on anticipation. In some studies, it was found that male athletes use different behavioral strategies compared to women (e.g. in ice hockey (Biserova & Gaifullina, 2018), but when comparing injuries in karate between men and women in a recent review (Thomas & Ornstein, 2018), no differences were observed. Thus, there is further need to examine gender differences in many sports, also in karate kumite. Due to the findings that men and women can use different mental and cognitive strategies and can also show different response behavior in order to physical differences, it is worth analyzing if men and women use similar anticipatory cues. On the other hand, to the best of our knowledge, there are no studies showing differences in gaze behavior or visual capacities. Therefore, we want to examine gender differences but do not expect any. In our opinion, age can also be an influencing factor on anticipation and decision-making because with increasing age also experiences in the sport itself as well as in competitions are higher. First competitions can take place when athletes become around 12 to 14 years. First competitions of national level often occur at the age of 16 years and first competitions of international level normally take place when athletes become 18-20 years. With increasing age, a higher belt rank can be achieved which also can be an indicator for a higher level of movement execution and experiences with different type of attacks and opponents.

In the current cross-sectional study, we want to analyze further the anticipatory signals in which karate athletes recognize upcoming attacks, and thereby extending the knowledge from previous studies (Petri, Bandow, Binder, Droste & Witte, 2018, Petri et al., 2016). We also subtract reaction times from the first reaction of the responding athlete to analyze the movement stage of the attack at the time of the attack perception. We use different movement stages here. While Petri et al. (2016) divided the attack motion itself, we focus on movement stages before the actual attack to examine early cues before the actual attack. Furthermore, we use individual measured reaction times from the unspecific reaction test of the Vienna test system because that test provides objective reaction time values, instead of using reaction time values taken from the literature.

Moreover, we want to examine the influence of gender, age and expertise on the perception. Here, we analyze in which movement stage the attack was recognized by examining the athletes' first reactions. We decided for an in-situ study to provide quite natural conditions, and to give the athletes the possibility to act sports specifically, which was demanded by Pinder, Davids, Renshaw and Araùjo (2011). Already Mori, Ohtani and Imanaka (2002), as well as Mori and Shimada (2013), highlighted the importance of natural conditions because only in sports specific tasks, experts can show their expertise and supremacy. While most of the previous research compared experts and novices, we want to investigate the anticipation behavior in expert and advanced karate athletes. Hence, the aim of the study is to consider reaction times to estimate the likely movement stage from where reaction-relevant information is retrieved in an almost natural setting. We further examine the influence of gender, age and expertise (measured by competition experience) on attack recognition.

We expect no differences between men and women because no previous study reported any differences in visual information intake. However, we assume that with increasing age and accompanying competition experience, athletes are able to recognize attacks at earlier times because of their greater expertise due to larger training experience. Furthermore, athletes change from national into international competitions and can have a training license.

2 Materials and Methods

The study was conducted in accordance with the ethical guidelines of Helsinki and obtained the acceptance of the university's ethic committee. All participants and their parents were informed about the aim and the procedure and gave their written consent prior to the beginning.

Participants

Twenty-four (n=24) experienced and healthy karate athletes (sex: 9 women and 15 men, age: M = 20.83 years, SD = 5.1 years; height: M= 175.67 cm, SD= 9.64 cm; weight: M= 69.98 kg, SD = 11.69 kg, all shotokan style) from the German karate association (DKV, Germany, n=12) and the German JKA-Association (DJKB, n=12) participated on voluntary basis. All athletes had at least eight years of karate experiences (range: 8-25 years) and five years of competition experience (range: 5-20 years). 12 athletes had blue belt and brown belt degree (3rd Kyu - 1st Kyu) and the other 12 had black belt degree (1st Dan – 4th Dan). 13 athletes had a training license and worked as coach.

Procedure

The athletes were assigned to pairs based on their performance level and gender to ensure conditions quite similar to normal competitions. In our in-situ study, the athletes performed a karate fight in an area of 6 x 4 m (Fig.1). For each pair, one athlete was always the attacker and the other one was the defending athlete. All attacks as well as reactions were carried out as natural as the athletes would do in a real competition to score a point. Therefore, we gave no time limit to the attacker in order to prepare and perform the attack. The offending athlete was instructed in written which attack should be performed whereas the defending athlete remained clueless about the attack type. The defending athlete should only respond if s/he was sure about an upcoming attack, but should not perform an own attack. Each attacker performed 15 attacks (5x Gyaku-Zuki (GZ), 5x Gyaku-Zuki overrun (GZo), and 5x Kizami-Zuki (KZ)) in randomized order. The order of the attacks was the same for all athletes, but due to the randomization, no athlete memorized the actual order. However, all athletes were aware that only arm attacks occurred which are the most often performed attacks in karate kumite. Afterwards, the athletes changed the role. All attacks and reactions were recorded in parallel using four high-speed cameras (Contemplas, Weilheim, Germany, 100 Hz).

We chose those attack types (all arm attacks) according to a previous competition analysis in which it was found that these three attacks are used most frequently and successfully in international karate kumite (Petri et al., 2017). GZ is the reverse punch. It is a punch with the rear hand while the athlete is in a stable position. GZo is a variation of GZ in a way that the reverse punch is performed during a movement forward. With GZo, it is possible to attack from larger interpersonal distances. KZ is performed with the front arm and without hip rotation, as it is the case in GZ and GZo. Thus, KZ is a quite surprising attack from a shorter interpersonal distance (see also Fig.1).

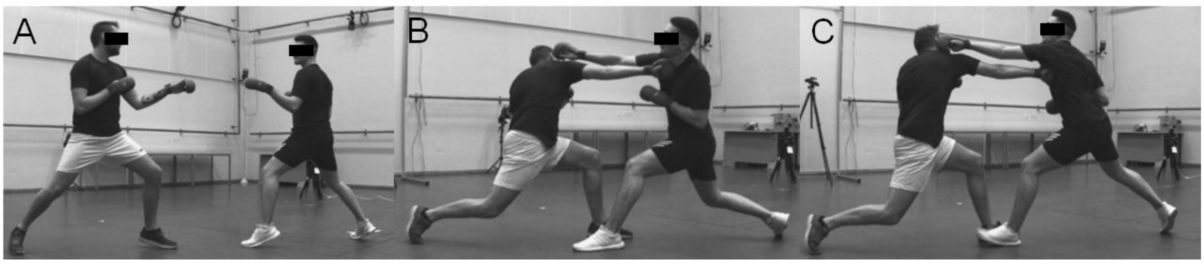

Fig. 1: Karate fight with the attacker on the right side and the responding athlete on the left side. A: The athletes waited in ready stance position for an audio start signal and performed the attacks from natural steppings. B: The attacker performs Gyaku-Zuki. C: The attacker performs Kizami-Zuki.

To analyze the anticipatory signals, we used video analysis software (Kinevea, version 0.8.15) and subtracted individual reaction times from the time of the first reaction of the responding athlete to examine the movement of the attacker at that time of the attack recognition. That method was already applied by Petri et al. (2016) using motion capturing instead of video analysis, in which 150 ms as literature value (based on Zaciorskij, 1971) was used as reaction time. The first reaction was either a movement in the front hand to initiate a block, a movement in the front hand or rear hand to perform a direct KZ or GZ, or a movement in the legs to initiate an evasive movement.

In the current study, individual unspecific reaction times were taken using the Vienna test system (Schuhfried, Vienna, Austria), especially the subtests S1 and S4 of the reaction test. Therefore, the athletes had to respond per single key press to stimuli on a computer screen. S1 is the unspecific simple reaction test towards a visual stimulus (yellow circle) without further distractors. S4 is a recognition reaction test towards a visual stimulus (yellow and red circles in parallel) with further visual (yellow or red circle only) and auditory distractors (sound). Here, the athletes were instructed to respond only when the yellow and red circles appeared simultaneously, but not when only one color showed up or when one color occurred together with the sound. Although that measurement is sports unspecific, it provides the advantage of objective and individual reaction time values. The Vienna test system is a validated and often-used instrument in sports and psychology tests. The reaction time measured by S1 and S4 is defined as time from the appearance of the stimulus on the screen until the release of the start button of the dominant index finger. We used both tests (S1 and S4), since the actual reaction times in karate kumite are still not clarified (Liu et al., 2018, Petri, Bandow, Binder, Droste & Witte, 2018).

We divided the attacks in four movement stages (MS1-4), which are valid for all three attack types (GZ, GZo, KZ). In movement stage 1, the attacker performed early and unrhythmical steppings in all directions to test the opponent and to prepare the own attack. Especially MS1 showed different time durations. Some athletes only performed one to three steps, which lasted only up to 1-2 seconds, while others performed several steps over up to 10 seconds. In movement stage 2, the attacker conducted the last step towards the opponent before the actual attack, which was a jump with both feet synchronously. Thus, a flight stage together with a reduction of interpersonal distance was observed. MS2 had a shorter time duration than MS1 but was still depending on the length and jump height of the last stepping. The time duration was about 0.5-2 seconds. Movement stage 3 was the landing phase after the flight and thus, the time duration was short (about 0.3-1 seconds). In movement stage 4, the attacker moved forward the front leg and initiated the main phase, which was the extension of the punching arm. Depending of the attack type, we observed different duration lengths. KZ is a short attack, thus time durations of only up to 0.5 seconds were observed. For GZo and GZ longer durations of up to 1-1.5 seconds were observed. For further details, see Table 1. We chose such large movement stages because they should be valid for all arm attacks and should also balance the lack of acuity in data recording. With the 100 Hz in data recording, each frame was taken only every 10 ms.

Table 1: Description of the movement stages for all three attacks: Kizami-Zuki (KZ), Gyku-Zuki (GZ) and Gyaku-Zuki overrun (GZo).

movement stage	**description**	**relevant partial movements**
1	early steps for attack preparation and testing of the opponent	• unrhythmical steps in all directions • lowering of the center of mass • pushing with the arms towards the opponent
2	last step towards the opponent before the attack	• lowering of center of mass to prepare the take • jump with both feet synchronously towards the opponents • fast reduction of interpersonal distance
3	landing after the flight stage in stage 2	• feet touch the ground (first the toes and then the heels) • bending of the knees after landing • extending of the knees after retaining the body weight
4	actual attack (main stage)	• lifting the front leg and moving forward • rotation of the hip and shoulders (GZ and Gzo) • extension of the punching arm up to around 170° in the elbow joint • pulling back of the punching arm and moving backward

When we subtracted the reaction times from the time of the first reaction to examine to which signals the responding athlete reacted, we analyzed at which movement stage the response occurred. The procedure how we analyzed anticipatory cues is also given in Figure 2. After the movement analysis, all participants filled in a feedback questionnaire, in which they were asked to which signals they thought they had reacted.

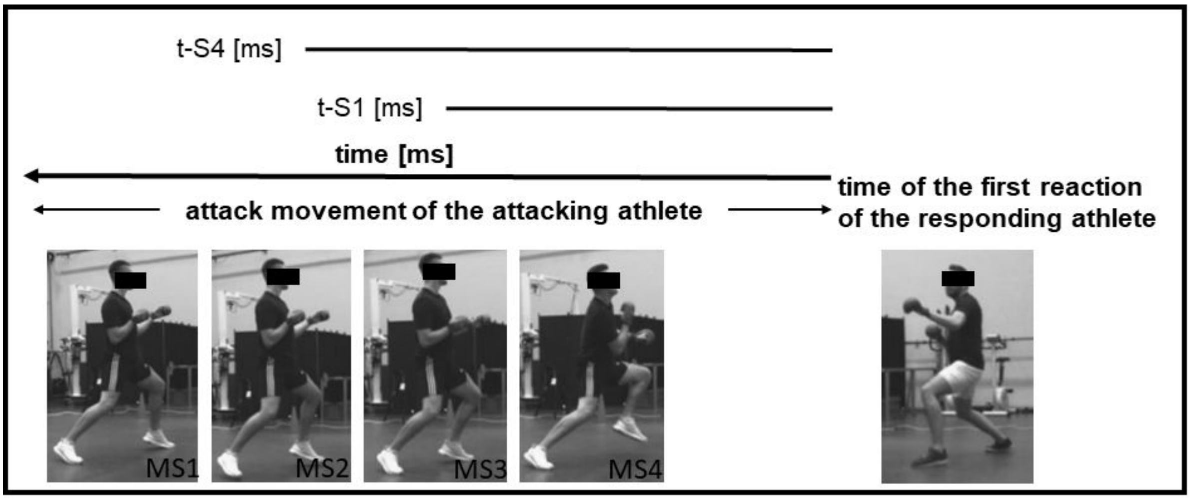

Fig. 2: Subtraction of the reaction times S1 (simple reaction time) and S4 (recognition reaction time) of the Vienna test system from the time of the first reaction of the responding athlete (right) to analyze to which movement stage (MS1-4, left) in the attack the response occurred. MS1: early steps. MS2: last step with flight stage for interpersonal reduction in distance. MS3: landing after MS2. MS4: step forward with the front leg and initiation of the punch.

Data analysis

In total, we recorded 360 videos (120 videos per attack type and 15 videos per participant) of both attack and reaction. However, we had to exclude nine videos due to technical problems. All videos were analyzed using the program kinovea (version 0.8.15). One rater (an experienced karate athlete, 1st Kyu) analyzed all videos, a second rater analyzed 50% of all data. Interrater reliability was assessed using Cohen's kappa coefficient being classified k<0.1 no reliability, k=0.1-0.3 fair, k=0.41-0.6 substantial, k=0.61-0.8 good, and k=0.81-1 very good. We achieved k=0.932, thus very good interrater reliability was given.

The sample group of 24 athletes was characterized according to the following influencing factors:

- gender: male athletes (n=15), 11 international level (9 black belt degree, 2 brown belt degree) and 4 national level (blue and brown belt degree), 10 with training license, 1 without training license versus female athletes (n=9), 4 international level (black belt degree) and training licence, 5 national level (brown and blue belt degree) and without license.
- expertise: athletes with international competition experience (n=15), including 11 men and 4 women, 11 with black belt degree, 4 with brown and blue belt degree, 12 with coach license, 3 without coach license versus athletes with national competition experience (n=9), including 4 men and 5 women, 1 black belt degree, 8 blue and brown belt degree, 1 with training license, 8 without training license.

All statistical analysis were carried out with SPSS (version 25, IBM, Germany) and a significance level of α=0.05. We performed analyses of variance (ANOVAs) with "movement stage" as outcome variable (MS 1-4) and with "reaction times" (metric values for S1 and S4) and "attack" (nominal values GZ / GZo / KZ) as influencing factors. The factor "reaction times" was included to analyze if there are differences between the used tests S1 and S4. The actual sports specific reaction times are not clarified, but maybe, based on our results, we can draw conclusions which subtest of the Vienna test system might be appropriate for future studies.

The movement stage is an ordinal-scaled variable because it is better to perceive attacks at an early stage for having more time for the reaction compared to a later stage. For each ANOVA, one of the further between-subjects' factors were included: gender (male / female), age (under 20 years / over 20 years), and level of expertise (national / international). Effect sizes were estimated using eta square (ŋ2) being defined as <0.06 small, 0.06-0.14 moderate, and >0.14 large effect. For the factor "attack", we conducted Bonferroni-post-hoc-tests to examine differences in attack recognition between the three attack types.

Furthermore, unpaired t-tests were applied to analyze differences between men and women, and between athletes with international and national competition experience.

Additionally, to analyze how "age" affects attack recognition, we carried out a correlation analysis between age and recognized movement stage using Pearson's bivariate correlation coefficient (r), being defined as r=0.10 low correlation, r=0.3 moderate correlation and r=0.5 high correlation. The feedback questionnaire was analyzed descriptively.

3 Results

First, we present the reaction time values and the kind of reaction. Afterwards, we show the results of the ANOVAs, t-tests and correlations to shed light on how the factors "age", "gender" and "expertise" affect the movement stage in which the opponent recognized an upcoming attack. Finally, we present the results of the feedback questionnaire.

Results of the reaction time values for S1 and S4 and kind of reaction of the athletes

The reaction times for S1 were in the range of 166 ms to 246 ms (M = 213 ms, SD = 21.5 ms) and the values of S4 were within 255 ms and 372 ms (M = 297 ms, SD = 36.42 ms). For further detail see Table 2.

The kind of reaction was similar in GZ, GZo and KZ and for all attacks together as follows: 32.5% direct attack without previous block or defence, 38.1% counterattack (block or evasive movement before the attack), 29.4% only block or evasive movement.

Table 2: Reaction times from S1 and S4 tests (mean and SD values) of each subgroup. S1: simple unspecific reaction test using the Vienna test system. S4: unspecific recognition/choice reaction test using the Vienna test system.

factor	participants	reaction times S1 [ms]	reaction times S4 [ms]
gender	female (n=9)	219.89 ± 18.54	313 ± 0
	male (n=15)	209.67 ± 22.82	292.40 ± 34.35
age	under 20 years (n=12)	212.64 ± 16.84	304.27 ± 34.74
	over 20 years (n=12)	214 ± 24.46	296.61 ± 36.83
expertise level , competition experience	international (n=15)	210.13 ± 24.77	293.67 ± 35.73
	national (n=9)	219.11 ± 14.08	310.88 ± 33.83

Results of the movement stages at the time of the attack recognition

Descriptive statistics about the movement stages, in which the attacks were recognized are shown in Table 3 and Figure 3. Regardless of age, gender and expertise, the most often used movement stage in which all athletes recognized the attacks, was movement stage 2 (reduction of interpersonal distance during the last step before the attack). The movement stages to which the athletes responded are provided in Figure 3.

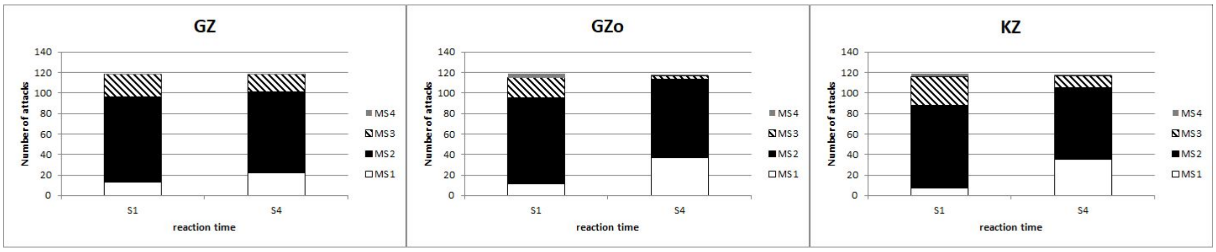

Fig. 3: Distribution of the movement stages (MS1-4) in the three attacks Gyaku-Zuki (GZ), Gyaku-Zuki overrun (GZo) and Kizami-Zuki (KZ) for the reaction times S1 (simple reaction time towards a visual stimulus) and S4 (recognition reaction time of one visual stimulus in a field of several distractors).

Results of the influencing factors "age", "gender" and "expertise level" on the movement stages in which the attack was recognized using ANOVAs and post-hoc tests

In the following, we show how the analyzed factors "age", "gender", and "expertise level" have an effect on the dependent variable "movement stage". Furthermore, we analyze if there are any differences between S1 and S4 as objective reaction times, and if there are differences between the three attack types (GZ, GZo and KZ).

We found a significant effect for the factor “age” with F(1/396) = 17.835, p>0.001, but only with a small effect (ŋ2=0.043), so that this factor might be negligible. We detected a significant difference for the factor “reaction time” with F(5/396)=112.329, p>0.001, ŋ2=0.586 (large effect), but probably only due to the reason that the simple reaction test S1 provides shorter reaction times than the choice reaction test S4 (see also Tab.2). No significant difference was observed for the factor “attack” with F(2/396)=2.693, p=0.069. Additionally, no significant interaction effects were found for “age x reaction time” (F(5/396)=1.186, p=0.315), for “attack x reaction time” (F(19/396)=0.255, p=0.990) and “age x attack x reaction time” (F(10/396)=0.132, p=0.999). Thus, the age and the attack type do not seem to have a relevant influence on the recognized movement stage.

We detected a significant difference in the factor “gender” with F(1/396)=12.073, p=0.001, but again with only a small effect (ŋ2=0.03) and in the factor “reaction time” with F(5/396)=106.733, p>0.001, ŋ2=0.574 (large effect). No significant difference was observed for the factor “attack” with F(2/396)=2,106, p=0.123. Furthermore, no interaction effects were found for “gender x attack” (F(2/396)=0.923, p=0.398), for “gender x reaction time” (F(5/396)=1.02, p=0.406), and for “gender x attack x reaction time” (F(10/396)=0.225, p=0.994. In summary, similar results were shown for “gender” and “age. In general, no interaction effects were found, thus, the type of attack and the used reaction tests did not have an influence on the factors “age” and “gender”.

For “expertise - competition experience”, we found significant effects for the factors “competition experience” (F(1/396)=60.997, p<0.001, ŋ2=0.133 (moderate effect), “attack” (F(2/396)=3.387, p=0.035, ŋ2=0.017, small effect), and “reaction time” (F(5/396)=128.176, p<0.001, ŋ2=0.618 (large effect). Athletes with international competition experience responded earlier than athletes with national competition experience. Again, reaction times of S1 were shorter than of S4 due to the previously described reason. An interaction effect was given for “competition experience x reaction time (F(5/396)=3.717, p=0.003, ŋ2=0.045 (small effect). No interactions effect were found for “competition experience x attack” (F(2/396)=1.351, p=0.260), for “attack x reaction time” (F(10/396)=0.362, p=0.962), as well as for “competition experience x attack x reaction time” (F(10/396)=0.209, p=0.995). In summary, due to the shorter reaction times in S1 (because the task is easier) compared to S4, we found a significant effect on all analyzed factors. The factors “age” and “gender” did not seem to have a relevant influence on the recognized movement stage, though the expertise level did. Athletes of international level responded earlier than athletes of national level. The attack type had only an influence on the expertise level but not on age and gender.

Post-hoc tests for the factor “attack” indicated a significant difference between GZ and KZ (p=0.048), but not between GZ and GZo (p=0.99) and between KZ and GZo (p=0.144). KZ was recognized later compared to GZ, especially by athletes of lower level, what is in line with a previous study (Petri, Bandow, Binder, Droste & Witte, 2018). That result was regardless of age and gender and can be explained by the fact that KZ is a surprising attack with the front arm, which is closer to the opponent than the attacking arm (rear arm) when conducting GZ. KZ, when performed well, occurs without any preparatory movement, like hip rotations (Petri et al., 2016).

Results of the t-tests as further post-hoc tests for analysis of the effects of the factors "gender" and "expertise" on the dependent variable movement stage.

Unpaired t-tests as additional post-hoc tests showed a significant difference ($p<0.05$) for the factors "expertise - competition experience" using S1 as reaction time, but not using S4. No significant differences were found for the factor "gender" (both $p>0.05$), which is in line with the only small effect when conducting ANOVA. For further details, see Table 3.

Table 3: Means ± standard deviations for all attacks of the movement stages to which the attacks were recognized based on the several reaction times. S1: simple reaction time towards a visual stimulus. S4: Recognition reaction time of one visual stimulus in a field of several distractors. Comparisons between the subgroups for each factor were carried out using unpaired t-tests.

factors	**participants**		**S1 [ms] movement stage (1-4) M ± SD**	**significance** (using unpaired t-tests)	**S4 [ms] movement stage (1-4) M ± SD**	**significance** (using unpaired t-tests)
gender	male	n=15	2.1 ± 0.4	T=0.805, p=0.429	1.7 ± 0.4	T=0.963 p=0.346
	female	n=9	2.2 ± 0.4		1.9 ± 0.3	
expertise – competition experience	inter-national	n=15	2.0 ± 0.3	T=2.361 p=0.028	1.7 ± 0.3	T=1.775 p=0.090
	national	n=9	2.4 ± 0.4		2.0 ± 0.1	

Based on the statistical tests, we conclude that gender does not have a relevant influence on anticipation in karate kumite since no significant differences between men and women were observed. However, due to a significant difference between athletes of national and international competition experience in S1, we assume that the level of expertise affects the attack recognition. Athletes of international performance level outperform those of national level, as it was already shown in several studies (e.g. Matsushita & Yamada, 1998, Mori, Ohtani & Imanaka, 2002, Mori & Shimada, 2013). We found no significant differences for the factor expertise in S4. Due to the lack of individual and sports specific reaction times measurements in karate, we chose both values (S1 and S4), but it is possible that both do not fully represent the reaction times. Until the correct reaction times (or instruments for their assessment) exist, we recommend to use both values. However, S1 seems to be more sensitive based on our results.

Results of the correlation analyses as further post-hoc tests for the effect of the factor "age" on the dependent variable "movement stage"

We found low correlations between age and GZ S1 (p=0.485, r=-0.150), as well as between age and GZo S1 (p=0.175, r=-0.286), and a moderate correlation between age and KZ S1 (p=0.132, r=-0.317). For S4, we found low correlations between age and GZ (p=0.305, r=-0.219), between age and GZo (p=0.605, r=0.111), and between age and KZ (p=0.688, r=-0.087). In summary, we did not observe relevant correlations (all p>0.05) between the factor "age" and the movement stage to which the athletes responded in all three arm attacks. Thus, the factor age alone has no effect on the attack recognition in the attacks GZ, GZo and KZ in our sample (athletes with an age of 16-31 years). We can conclude that the factor "expertise level – competition experience", which usually comes along with increasing age, is the most important factor for early recognition of attacks.

Results of the feedback questionnaires

We asked the athletes in open questions to which signals they responded and which signals were important for them to recognize upcoming attacks correctly. Three quarters of the athletes was unable to verbalize the knowledge as it was reported in previous studies (e.g. Kelly, Healy, Moran & O'Connor, 2011). They were not sure about the actual used cues and named imprecise terms, such as "instinct" or "intuition". A few athletes named the movement of the rear foot, movements in the trunk or the shoulders and a "feeling for distances" as important cues while others stated the importance of the arm motions. In summary, movements of the opponent's body were reported to be relevant for attack recognition as it was verified in previous studies (e.g. Abernethy, Zawi & Jackson, 2008, Belling, Suss & Ward, 2015, Russo & Ottoboni, 2019).

4 Discussion

We chose a study design with quite natural conditions, such as freedom of movements and the possibility of sports specific attacks and reactions, as it was already demanded (Müller, Brenton, Dempsey, Harbaugh & Reid, 2015, Pinder, Davids, Renshaw & Araùjo, 2011). The current study represents a novel attempt to analyze anticipation in karate kumite using an in situ experimental paradigm.

We examined anticipatory signals based on subtraction of individual and objective measured reaction times (S1 and S4 of the reaction test of the Vienna test system) from the time of the first reaction of the responding athlete to analyze the relevant movement stages, which were used for attack recognition. We extended previous work (Petri et al., 2016) and investigated group differences between different expertise levels: experts and advanced karate experts. We further analyzed the influence of expertise level, gender and age on attack recognition. Regardless of age, gender and expertise, early movement stages (steps for attack preparation in MS1 and reduction of interpersonal distance during the last step before the attack in MS2, see Tab. 1) are important cues in the three arm attacking techniques GZ, GZo and KZ (see Fig. 3).

Therefore, early steps, especially the last step before the actual arm attack, and the reduction of interpersonal distance seem to serve as universal anticipatory cues (at least for athletes of national level with an age of 16-31 years).

As we expected, we found no difference in relevant movement stages between men and women. Although the ANOVAs showed a significant effect of gender, the effect size was only small, and we could not find a significant gender difference in the t-tests. Therefore, we can argue either that our sample size is too small or that the groups were not completely homogenous. In the included sample, the men had a little higher expertise level than the women. However, we found differences regarding the expertise. Athletes with international competition experience outperformed athletes with national competition experience using the reaction time S1, but not S4. For the factor “age”, we also found no relevant effect on the attack recognition. Therefore, we conclude that regardless of national or international competition experience, movement stage 2 reveals anticipatory cues, as long as the national or international competition experience is at least five years. However, the movement stages were quite long phases (see procedure section). In case of further division of the stages, it is possible to see further differences.

Using the ANOVAs, there was no significant difference in attack recognition between the three arm attacks GZ, GZo and KZ for the factors “gender” and “age”. Only for the factor “experience”, we observed a significant difference between the three attacks. KZ was harder to recognize than GZ and GZo. That might be due to the fact that KZ is performed with the front arm, and is therefore conducted from a smaller interpersonal distance and also conducted without further preparing movements. It is just the extension of the front arm without hip rotation. Thus, that attack is very surprising, especially for intermediates. That result is in line with the study by Petri, Bandow, Binder, Droste and Witte (2018).

We found movement stage 2 (last step before the attack and reduction of distance between the opponents) to contain anticipatory signals both for athletes of expert and advanced levels in all three types of attacks. That supports previous results (Okumura, Kijima & Yamamoto, 2017, Okumura et al., 2012, Petri et al., 2016, Usui, Okumura & Kudo, 2018), in which it was found that distance estimation and reductions of distances are crucial for successful anticipation in martial arts. In addition, preparation stages, in this case the early steps in movement stage 1, seem to contain anticipatory cues. Based on the “Just-in-time”-principle (Schorer, 2007), high-skilled athletes with fast motor responses react later to signals and are less prone to deceptive movements compared to athletes with slower motor response times (Dicks, Davids & Button, 2010, Savelsbergh, Williams, van der Kamp & Ward, 2002). Although deceptive movements were not analyzed in the current study, and participants were instructed to perform only one single attack without any pushing or feints, experts expect more feints than novices due to their large movement experience (Mori & Shimada, 2013). Thus, we can assume that although movement stage 2 was the most frequently used stage to which athletes responded, also movement stage 1 might be important. According to the affordance-based control (Fajen, 2005), reactions occur due to stimuli in the environment and are always connected to own motor skills.

Based on body skills, reactions are performed at the right place at the right time (Fajen, 2005, van der Kamp, Dicks, Navia & Noel, 2018). Given that affordance-based theory, the athletes from our study seemed to have quite similar body skills.

Williams, Huys, Cañal-Bruland and Hagemann (2008) detected that attacks in ball sports are often recognized by the end-effectors (often the arms or the racquet). However, in karate-kumite that would not be appropriate. In that case, attacks would be recognized in movement stage 4 and there would not be enough time for the own motor response due to the close distance between the opponents. Therefore, in karate-kumite, attacks must be recognized earlier. According to Table 1, early and unrhythmical steps to prepare the attack contain a lowering of the center of mass and a pushing of the arms to test the reactions of the opponent. That pushing often comes together with a short rotation of the shoulder axis (when testing GZ). In movement stage 2, we observe again a lowering of center of mass to prepare the last step forward before the attack. That last step is often a jump being higher und further towards the opponent than the steps before. The lowering of center of mass also leads to a stronger step forward to perform the reduction of interpersonal distance very fast. Therefore, that last step (together with the lowering of center of mass) seems to be an important cue.

Moreover, we observed some individual signals at the attackers, which could also have been used by the responding athletes as relevant signals: movements in the head, laterally lifting of the elbow of the punching arm or lifting the front knee before the forward motion in movement stage 4. However, these signals were not observed at all attackers. In future studies with a larger and more homogenous sample size, these observed movements should be investigated further to examine individual differences rather than group differences (Müller, Brenton, Dempsey, Harbaugh & Reid, 2015). Therefore, a motion capturing system with synchronous recording of both athletes should be used as applied by Petri et al. (2016).

Limitations of the study

First, we have to mention critically that all participants who performed the fight against each other were already familiar to their opponent. Therefore, on the one hand, it could be interesting to repeat the study with athletes who do not know each other prior to the beginning. On the other hand, world-elite athletes in almost every sports know each other from previous competitions or even have some video material about the opponents for concreate competition preparation.

Second, although the total sample size of twenty-four experienced karate athletes is not low, the sample size of the subgroups should be increased in future studies. Furthermore, the subgroups were not completely homogeneous regarding age, gender and expertise. That issue should be addressed in future studies.

Third, we analyzed the attack recognition to examine anticipatory cues but we did not investigate the response quality. We decided to remove that parameter from our analysis due to the isolated experimental condition of only one attack and only one response. To analyze the response quality additionally, it would be better to analyze karate kumite competitions and to integrate the referee decision into such a further analysis.

Fourth, we used an in-situ approach to analyze reactions in quite natural conditions. However, in our design, the defending athlete was focusing continuously on the attacking athletes to prepare the appropriate defense. S/he was instructed to perform only defending movements or attacks in case of an upcoming attack and not to perform own early attacks. Probably, in real competitions, in which both athletes can perform early attacks and also attack combinations, reaction might be slightly different. Then, differences in expertise level, age or gender might be more pronounced. Therefore, it would be desirable to apply our approach with reductions of reaction times to analyze relevant movement stages containing anticipatory cues in video footage from real competitions.

Future directions

Based on our findings of the importance of the preparatory movements before the actual arm attacks, it could be useful to divide further the movement stages 1 and 2 into more detailed stages to better isolate the relevant cues in space and time. Furthermore, for analysis of kinematics, it would be desirable to use motion capturing instead of video analysis. That would give more precise movement data but would also be more time-consuming. In any case, the current results can be useful for integration into the model of Martínez de Quel and Bennett (2019), which describes the perception-action relationship in combat sports involving a physical preparation between opponents based on distance, attack progression and opponents' reactions.

Although Dicks, Davids and Button (2010) doubt universal strategies in anticipation, we found reductions in interpersonal distance as universal cue in karate kumite. However, it could be possible that every athlete also uses additional different anticipatory cues based on previous experiences. Furthermore, it could be the case that the used anticipatory cues are recognized at different times and processed differently between several athletes, although the performance outcome might be similar. That could be an interesting field for future research. Furthermore, as was already described by Loffing and Cañal-Bruland (2017), situation probabilities and pattern recognition might be used by the athletes. They recognized the early steps together with the lowering of body of mass together with a pushing of the arms or a hip rotation. Already Petri, Bandow, Salb and Witte (2018) showed that although athletes fixate a visual pivot (often the athletes head), they used the body kinematics (movements of the arms, hip and legs). Therefore, it would be interesting (if possible) to analyze the combination of several relevant cues to detect the pattern. Such knowledge could be used to enhance movement learning and training.

Dicks, Button, Davids, Chow and van der Kamp (2017) demand natural learning conditions with variability to ensure adequate adaptations of the athletes towards changing environments and movement patterns. Although each athlete should be able to perform several movement executions and attacks to be unpredictable for opponents, everyone has own movement preferences (Mann, Schaefers & Cañal-Bruland, 2014). The findings of the present study can be used to optimize karate and other martial arts training to sensitize athletes, coaches, and especially novice athletes for correct estimation of distance to the opponent and the stepping behavior. A lowering of the body to prepare the flight stage for interpersonal distance reduction or a change in the shoulder axis can be important signals for an upcoming attack. That purpose could be learned under different conditions.

5 Conclusion

We found that the reduction of interpersonal distance and early steps to prepare the attack are anticipatory cues for both men and women, and experts and advanced karate athletes with an age of 16 to 31 years, which is a common age of active competition participation. Therefore, these cues seem to be universal. The method presented in the current study can be interesting for both research and training either in karate or other martial arts, as well as racquet sports or other 1:1 sports scenarios.

Declaration of Interest

The authors declare that they have no known competing financial interest or personal relationships that could have appeared to influence the work reported in this paper.

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References

Abernethy, B., Zawi, K. & Jackson, R. C. (2008). Expertise and attunement to kinematic constraints. *Perception*, 37, 931-938. DOI: 10.1068/p5340

Afonso, J. Garganta, J. & Mesquita, I. (2012). Decision-making in sports: the role of attention, anticipation and memory. *Revista Brasileira de Cineantropometria e Desempenho Humano*, 14 (5), 592-601. DOI: 10.5007/1980-0037.2012v14n5p592

Bandow, N. (2016). Bestimmung der Antizipationsfähigkeit im Karate-Kumite unter Nutzung der virtuellen Realität. [Analysis of anticipation in karate kumite by use of virtual reality]. *Berlin: epupli Verlag*. ISBN: 978-3-7418-0131-0.

Belling, B. K., Suss, J. & Ward, P. (2015). Advancing theory and application of cognitive research in sport: Using representative tasks to explain and predict skilled anticipation, decision-making, and option-generation behavior. *Psychology of Sport and Exercise*, 16(1), 45-59. DOI:10.1016/j.psychsport.2014.08.001

Biserova, G.K. & Gaifullina, N.G. (2018). Junior female ice hockey players; behavioural strategies in training process. *Theory and Practice of Physical Culture*, 3, 15-17.

Cagri Cetin, M., Tasgin, Ö. & Arslan, F. (2011). The relationship between reaction time and decision-making in elite kickboxing athletes. *World Applied Sciences Journal*, 12 (10), 1826-1831.

Contiero, D., Kosiewicz, J. & Baker, J. S. (2018). Karate: Emotions and movement anticipation. Physical Culture and Sport. *Studies and Research*, LXXIX: 62-71. DOI: 10.2478/pcssr-2018-0021

Dicks, M., Button, C., Davids, K., Chow, J. Y. & van der Kamp, J. (2017). Keeping an eye on noisy movements: On different approaches to perceptual-motor skill research and training. *Sports Medicine*, 4, 575-581. DOI: 10.1007/s40279-016-0600-3

Dicks, M., Davids, K. & Button, C. (2010). Individual differences in the visual control of intercepting a penalty kick in association football. *Human Movement Science*, 29 (3), 401-411. DOI: 10.1016/j.humov.2010.02.008

Fajen, B. R. (2005). Perceiving possibilities for action: On the necessity of calibration and perceptual learning for the visual guidance of action. *Perception*, 34, 717-740.

Kelly, P., Healy, A., Moran, K. & O'Connor, N.E. (2010). A virtual coaching environment for improving golf swing technique. In: *Proceedings of the ACM Workshop on Surreal Media and Virtual Cloning (SMVC'10)*. Florence, Italy. New York, NY, USA: ACM Press, 51-2.

Liu, Y.-H., See, L.-C., Chang, S.-T., Lee, J-S., Shieh L.-C., Ning, Y.-L., Lim, A.Y. & Chen, W.-M. (2018). Simple and choice response time among elite and novice karate athletes and non-athletes. *Archieves of Budo*, 14, 267-276.

Loffing, F. & Cañal-Bruland, R. (2017). Anticipation in sport. *Current Opinion in Psychology*, 16, 6-11. DOI: 10.1016/j.copsyc.2017.03.008

Mann, D. L., Schaefers, T. & Cañal-Bruland R. (2014). Action preferences and the anticipation of action outcomes. *Acta Psychologica*, 152, 1-9. DOI: 10.1016/j.actpsy.2014.07.004.

Martínez de Quel, M. & Bennett, S. (2019). Perceptual-cognitive expertise in combat sports: a narrative review and a model of perception-action. *Revista Internacional de Ciecias del Deporte*, 58 (15), 232-338. DOI: 10.5232/ricyde2019.05802

Matsushita, M. & Yamada, Y. (1998). A study on the anticipation of attacks in karate. *Japanese Journal of Sport Education*, 8 (2), 33-38. DOI: 10.7219/jjses.8.2_33

Milazzo, N., Farrow, D. & Fournier, J. (2014). Enhancing the decision making of skilled karate athletes with a "no-feedback" perceptual training program. *Archieves of Budo, Science of Martial Arts*, 10: 261-271.

Mori, S., Ohtani, Y. & Imanaka, K. (2002). Reaction times and anticipatory skills of karate athletes. *Human Movement Science*, 21, 213–230.

Mori, S. & Shimada, T. (2013). Expert anticipation from deceptive action. *Attention, Perception & Psychophysics*, 75, 751–770.

Morris-Binelli, K. & Müller, S. (2017). Advancements to the understanding of expert visual anticipation skill in striking sports. *Canadian Journal of Behavioral Science*, 49, 262-268. DOI: 10.1037/cbs0000079

Müller, S. & Abernethy, B. (2012). Expert Anticipatory Skill in Striking Sports: A Review and a Model. *Research Quarterly for Exercise and Sports, Physical Education, Recreation and Dance*, 83 (2), 175-187.

Müller, S., Brenton, J., Dempsey, A. R., Harbaugh, A. G. & Reid, C. (2015). Individual differences in highly skilled visual perceptual-motor striking skill. *Attention, Perception & Psychophysics*, 77: 1726-1736.

Müller, S., Gurisik, Y., Hecimovich, M., Harbaugh, A. G. & Vallence, A.-M. (2017). Individual differences in short-term anticipation training for high-speed interceptive skill. *Journal of Motor Learning and Development*, 5, 160-176. DOI: 10.1123/jmld.2016-0029

Okumura, M., Kijima, A. & Yamamoto, Y. (2017). Perception of affordances for striking regulates interpersonal distance maneuvers of intermediate and expert players in kendo matches. *Ecological Psychology*, 29 (1), 1-22. DOI: 10.1080/10407413.2017.1270147

Okumura, M., Kijima, A., Kadota, K., Yokoyama, K., Suzuki, H. & Yamamoto, Y. (2012). A critical interpersonal distance switches between two coordination modes in kendo matches. *Plos One*, 7 (12): e51877.

Petri, K., Bandow, N., Binder, J., Droste, M. & Witte, K. (2018). Antizipation im Karate-Kumite [Anticipation in karate kumite]. In: I. Fichtner (Hrsg.), Technologien im Leistungssport 3: Schriftenreihe für Angewandte Trainingswissen-schaft. *Aachen: Meyer und Meyer*, 13: 74-88.

Petri, K., Bandow, N., Masik, S. & Witte K. (2019). Improvement of early recognition of attacks in karate kumite due to training in virtual reality. *Journal Sport Area*, 4 (2), 294-308. DOI: 10.25299/sportarea.2019.vol4(2).3370

Petri, K., Bandow, N., Salb, S. & Witte K. (2018). The influence of facial expressions on attack recognition and response behaviour in karate kumite. *European Journal of Sports Science*, 19(5), 1-10. DOI: 10.1080/17461391.2018.1536170

Petri, K., Emmermacher, P., Danneberg, M., Masik, S., Eckardt, F., Weichelt, S., Bandow, N. & Witte, K. (2019). Training using virtual reality improves response behavior in karate kumite. *Sports Engineering*, 22:2. DOI: 10.1007/s12283-019-0299-0

Petri, K., Lichtenstein, M., Bandow, N., Campe, S., Wechselberger, M., Sprenger, D., Kaczmarek, F., Emmermacher, P. & Witte, K. (2016). Analysis of anticipation by 3D motion capturing – a new method presented in karate kumite. *Journal of Sports Sciences*, 35 (2): 130-135. DOI: 10.1080/02640414.2016.1158851.

Petri, K., Masik, S., Danneberg, M., Emmermacher, P. & Witte, K. Possibilities to use a virtual opponent for enhance-ments of reactions and perception of young karate athletes. *International Journal of Computer Science in Sport*, 18 (2) (Special Edition), 20-33. DOI: 10.2478/ijcss-2019-0011

Petri, K., Witte, K., Bandow, N., Emmermacher, P., Masik, S., Danneberg, M., Salb, S., Zhang, L. & Brunnett, G. (2017). Development of an autonomous character in karate kumite. In: Proceedings of the 11th International Symposium on Computer Science in Sport (IACSS 2017), Advances in Intelligent Systems and Computing. *Springer International Publishing*, 663, 124-135. DOI: 10.1007/978-3-319-67846-1_13

Pinder, R. A, Davids, K., Renshaw, I. & Araùjo, D. (2011). Representative learning design and functionality of research and practice in sport. *Journal of Sport and Exercise Psychology*, 33 (1), 146-155.

Runswick, O. R., Roca, A., Williams, A. M. & McRobert, A. (2018). The temporal integration of information during antic-ipation. *Psychology of Sport & Exercise*, 37: 100-108. DOI: 10.1016/j.psychsport.2018.05.001

Russo, G. & Ottoboni, G. (2019). The perceptual-cognitive skills of combat sports athletes: A systematic review. *Psychology of Sport and Exercise*, 44, 60-78. DOI: 10.1016/j.psychsport.2019.05.004

Savelsbergh, G. J. P., Williams, A. M., van der Kamp, J. & Ward, P. (2002). Visual search, anticipation and expertise in soccer goalkeepers. *Journal of Sports Sciences*, 20 (3), 279-287.

Schorer, J. (2007). *Höchstleistung im Handballtor – Eine Studie zur Identifikation, den Mechanismen und der Entwicklung sensomotorischer Expertise [Maximum performance in the handball goal – A study for identification of mechanisms and development of sensorimotor expertise]*. Doctoral thesis, University Heidelberg, Germany.

Thomas, R. E., Ornstein, J. (2018). Injuries in karate: Systematic review. *The Physician and Sportsmedicine*, 46 (3), 279-303. DOI: 10.1080/00913847.2018.1472510

Usui, N., Okumura, M. & Kudo, K. (2018). Expertise differences in movement switching in kendo players. *International Journal of Sport & Health Science*, 16, 19-26. DOI: 10.5432/ijshs.201719

van der Kamp, J., Dicks, M., Navia, J. A. & Noel, B. (2018). Goalkeeping in the soccer penalty kick. It is time we take affordance-based control seriously! *German Journal of Exercise and Sport Research*, 48, 169-175. DOI: 10.1007/s12662-018-0506-3

Venkatraman, J., Manwar, R. & Avanaki, K. (2019). Development of a punch-o-meter for sport karate training. *Electronics*, 8 (7), 782. DOI: 10.3390/electronics8070782

Williams, A. M. & Elliott, D. (1999). Anxiety, Expertise, and Visual Search Strategy in Karate. *Journal of Sport & Exercise Psychology*, 21, 362-375.

Williams, A. M., Huys, R., Cañal-Bruland, R. & Hagemann, N. (2008). The dynamical information underpinning antici-pation skill. *Human Movement Science*, 28, 362-370. DOI: 10.1016/j.humov.2008.10.006

Zaciorskij, V. M. (1971). Theorie und Praxis der Körperkultur – Die körperlichen Eigenschaften des Sportlers [Theory and application of body culture – The physical characteristics of an athlete]. *Sportverlag Berlin*.