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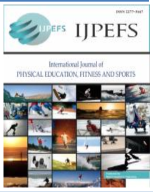

Comparison of response quality and attack recognition in karate kumite between reality and virtual reality – a pilot study

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Abstract: Virtual reality (VR) is an often-used instrument in sports science research and practical training. However, VR studies with experienced athletes and sports specific tasks are rare. Furthermore, the transfer from interventions in VR into reality is even less investigated. It is possible to analyze benefits of VR using in-situ studies comparing human behavior in VR with reality. If no differences occur in the human behavior, then VR would be appropriate for interventions to improve athletes' performance. Therefore, we let seven karate athletes respond each to ten attacks of a real attacker (reality) and a virtual attacker (VR using a Head Mounted Display) and compared the parameters "response quality" and "attack recognition" under both conditions. As attacks we chose Gyaku-Zuki (reverse punch, GZ) and Kizami-Zuki (attack with the front arm, KZ). ANOVAs and sign tests showed isolated cases of significant differences between both conditions: response quality in KZ, and attack recognition for 150ms in GZ, all $p<0.05$; $p>0.05$). The remaining comparisons showed no significant differences ($p>0.05$). We conclude that further research is needed but the results of the present pilot study are promising to assume that VR is suitable for applications because similar performance outcome in reality and VR were obtained.

Key Words: Virtual Reality, Vr, Head Mounted Display, Karate Kumite

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learning, anticipation in combat sports, development of sports interventions with senior healthy and diseased patients, as well as sports technology and sports equipment.

1. Introduction

For 20 years, virtual reality (VR) has been an often-used instrument in sports science research to analyze perception, decision-making, anticipation, and motor behavior [1], as well as in sport training [2-4]. VR provides many advantages, such as depth information, interaction (the VR adapts according to the user's view or the user's movements) and a high degree of realism. Already Bideau et al. (2003) showed in a handball study, in which real goalkeepers reacted to real and virtual handball throwers, that VR induces the same performance outcome as a real-world-setting, as long as the graphical level is realistic (attackers are natural rather than stick figures or point lights) [5, 6]. However, although the performance can be similar in reality and in VR, the movement executions can differ between both conditions [7].

There are only few studies in which performance due to interventions in VR and in reality was compared but most of them were carried out in the area of therapy. Several research groups [8-10] found that for some groups of patients (e.g. stroke patients) interventions (e.g. balance training) using VR were equally suitable like conventional training in reality, or even better. In high-performance sports and recreational sports, there exist several intervention studies using immersive VR, but most of them only analyzed beginners in unspecific tasks [11, 12]. For recommendations of VR intervention concepts, we refer to Stone et al. (2018) [13].

A study in baseball performed by Gray (2017) compared interventions in VR and conventional training and found that VR training leads to greater and longer lasting improvements than training in reality [2]. However, that described VR intervention was performed with a powerwall (one large screen), and thus, is not necessarily a full-immersive VR, which surrounds the user completely so that he can dive fully into the VR. In another VR intervention that was conducted by Petri et al. (2019a,b) [3, 14], karate athletes saw attacks of a virtual opponent in a Head Mounted Display (thus, full-immersive VR) and reacted to these attacks sports specifically. Unfortunately, in that study, the transfer into real training and competition could not be examined. Transfer is the most important component in each VR intervention to ensure that the benefits gained from VR are transported into reality. Only with that prove, we can suppose correctly that VR training leads to an increase in performance, and does not disturb the athletes, or in the worst case leads to a decline in performance in reality [15]. Burns and coworkers (2011) compared teaching three karate attacks in three conditions: with a real coach, a video and a virtual coach [16]. They could not find any differences in skill acquisition in novices and concluded that VR is as suitable as other methods for motor learning.

There is still a lack in intervention studies and cross-sectional studies using immersive VR, which examine high-skilled athletes in sports specific tasks, and also include transfer and retention tests [2, 15]. Furthermore, studies that compare human behavior, and especially sports specific behavior of advanced and expert athletes between reality and virtual reality, are still rare. However, such studies would be very useful to analyze if humans act as natural as in VR as they do in reality. If there occur no differences in the measured behavior, then we can assume that VR training interventions can be useful in sports and medicine to improve performance and health. Therefore, the aim of the present study is to analyze karate specific behavior in reality and in VR. We compare the sports specific response behavior of experienced karate kumite athletes by analyzing their response quality and their perception of attacks (attack recognition) in VR and in reality.

2. Methods

The study was part of a DFG- project (WI 1456/17-1), and therefore, ethical approval was obtained from the first author's university.

2.1 Participants

Seven youth karate kumite athletes of national level (four women and three men, 2nd – 1st Kyu) at the age of 15- 18 years took part in the present cross-sectional study on voluntary basis. They have been performing karate kumite at least for six years and already participated in national German competitions. All participants came from the DJKB (German JKA-Association) and performed the shotokan style. They, and their parents, were informed about the study and gave their written prior to the study. None of the athletes has performed a VR intervention before. All reported normal or corrected-to-normal vision and also 3D vision.

2.2 Procedure

All athletes performed a karate fight in two conditions: reality (R) and virtual reality (VR). In reality, they responded to attacks of a real opponent, and in VR, they responded to attacks of a virtual opponent (Fig. 1). In both conditions, the attacker conducted each five Gyaku-Zuki and Kizami-Zuki (both arm attacks) in randomized order, and the reacting athlete was instructed to respond as he would do in a natural competition. In both conditions, the participants had natural thus egocentric viewpoint, which was found to be better than allocentric viewpoint for fast and accurate decisions [17].

Gyaku-Zuki (GZ) is an attack with the rear hand towards the head or the chest of the opponent. Kizami-Zuki (KZ) is an attack with the front arm towards the opponent's head. These attacks were chosen according to a previous competition analysis, in which it was found that GZ and KZ are the most often and most successfully performed attacks in international karate kumite competitions [18].

The virtual opponent was created based on five high-skilled men (1st – 4th Dan), whose movements were recorded using motion capturing (Vicon, Oxford, UK, and ART, Weilheim, Germany). Later, a haut mesh (human body with a Karate Gi) for both a female and a male look were layed onto the movement data. The male version is shown in Fig. 1. The virtual environment was a sports hall with a fight area. For further detail, we refer to Petri et al. (2019a) [3].

Each karate fight was recorded with two high-speed cameras (Contemplas, Kempten, Germany, 100 Hz) in order to analyze the movements of the attacker and the reaction of the responding athlete in parallel. We examined the following parameters: response quality and attack recognition.

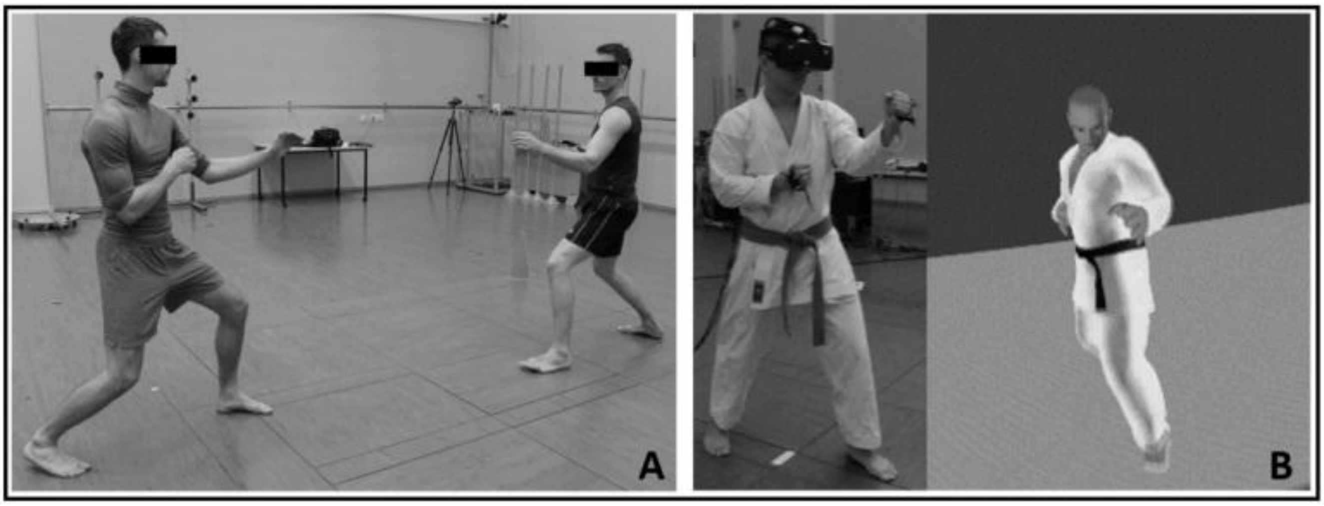

Figure1. Karate fight. An athlete responds to attacks of a real opponent (A) and a virtual opponent (B).

Response quality was assessed according to a scoring system, which was used previously [3]. The responding athlete received 0 points when the upcoming attack could not be prevented (too late or false response), 1 point when the attack could be prevented by a successful block or evasive movement which could be followed by a counterattack, or 2 points in case of a direct and successful attack.

Attack recognition was analyzed according to an already presented method [19]. We calculated back three different reaction times from the first reaction of the responding athlete to analyze the movement of the attacking athlete at that time of attack perception for investigation of the anticipatory signals, which are relevant for attack perception. We used the following reaction times: 150 ms [20], 255 ms and 370 ms [21]. Due to the lack of instruments with which it is possible to measure sports specific reaction times in karate (or other sports) we used these values from the literature. Because precise and sports specific reaction times in karate have not been identified yet, we used all three values and compared these.

To analyze the anticipatory signals, in which the athletes recognized the upcoming attacks, we divided the attacks in four movement stages (MS 1 – MS4) according to previous reference [22]. The following classification (Table. 1) is valid for both attacks (GZ and KZ).

2.3 Data analysis

We analyzed ten attacks (each five GZ and five KZ) in each condition, and thus, had 140 videos, in which we examined the parameters response quality and attack recognition using the video software Kineovea (version 0.8.15). Further statistics were carried out with SPSS (IBM, Germany, version 25). We performed ANOVAs for each parameter with condition (R versus VR), attack (GZ vs KZ), and reaction time (150 ms versus 255 ms versus 370 ms) as between-subjects' factors. For the factor reaction time, Bonferroni-post-hoc-tests were conducted. Effect sizes were estimated using eta square (η^2) and Cohen's d. Eta square is defined as $\eta^2<0.06$ small effect, 0.06-0.14 moderate effect and $\eta^2>0.14$ large effect. Cohen's d is defined as d=0.01 small effect, d=0.25 moderate effect, and d=0.4 large effect. Normal distribution was given. The scale level of both tested parameters was ordinal. Furthermore, sign tests comparing the conditions were carried out for each attack and each reaction time. The level of significance was set to $\alpha=0.05$ for all statistical tests.

3. Results

3.1 Response quality

The ANOVA showed a significant effect of condition on the response quality with $F(1/135)=13{,}702$, $p<0.01$, $\eta^2=0.004$, Cohen's d =0.063 (small effect), but no significant effect of attack on the response quality with $F(1/135)=0{,}567$, $p>0.05$.

Table 1 Classification of the four movement stages for Gyaku-Zuki and Kizami-Zuki

classification of movement stage	**explanation of the movement stage**
MS1	phase of early steps in all direction to prepare the attack and to test the opponent
MS2	last step towards the opponent. The attacker approaches the opponent by getting off the ground with both feet simultaneously and a flight phase→ shortening of the distance between both athletes
MS3	phase of the landing with both feet on the ground after the previous flight phase seen in MS2
MS4	main phase of the attack →moving forward of the front leg and moving forward of the punching arm

Although the main model was significant with F (3/135)=4,616, p=0.003, no significant interaction effects were found for condition x attack with F (1/135)=0,567, p>0.05. Corrected R square was 0.78, thus, 78% of the results can be explained by the model.

The sign tests comparing the conditions (R / VR) showed only a significant difference for the attack KZ (z-score=-2,942, p=0.003), but not for the attack GZ (p>0.05). In most cases, the kind of response was a combination of a block or evasive movement and a counter attack. As counter attack, GZ was conducted. That response type was observed in both conditions.

3.2 Attack recognition

The ANOVA showed a significant effect of condition on relevant movement stage (cue) with F (1/495)=20,739, p<0.001, η^2=0.049, Cohen's d=0,23 (small effect), and a significant effect of attack on relevant movement stage (cue) with F (1/405)=15,508, p<0.001, η^2=0.037, Cohen's d=0.19 (small effect), as well as a significant effect of reaction time (150ms / 255ms / 370ms) on movement stage (cue) with F (2/405)=157,648, p<0.001, η^2=0.438, Cohen's d=0.88 (large effect). The Bonferroni-post-hoc-tests revealed a significant difference between all three reaction times (p>0.001). The main model was significant with F (11/405)=32,912, p<0.001 and a corrected R square of 0.458. Thus, only 45,8% of the results can be explained by the model. No significant interactions were found for condition x attack, attack x reaction time, condition x reaction time, as well as attack x condition x reaction time (all p>0.05).

The sign tests comparing the conditions (R / VR) only showed a significant difference for GZ 150 ms (z-score= -2.971, p=0.003), but not for GZ 255ms, GZ 370ms or any reaction times in KZ (all p>0.05). Mean and standard deviations for all parameters, as well as the results of the sign tests are given in Table 2.

4. Discussion

Although we found significant differences between reality and VR in response quality and attack recognition, the effect sizes were only small. In general, all participants achieved a little better performance in reality compared to VR, what can be explained by the familiarity. VR was a new technology for all athletes, and they did not have a possibility to get familiar with it prior to the beginning of the study. Additionally, sign tests only showed single differences between the conditions (Tab. 2). Concerning response quality, the athletes achieved significantly worse performance for the attack KZ in VR compared to reality, while no significant differences were observed for GZ between the conditions. In most cases, the athletes achieved 1 point for the successful prevention of the upcoming attack by block or evasive movement and counter attack. GZ was the most often-used counter attack type in both conditions. In attack recognition, we only found a significant difference between VR and reality for the attack GZ when subtracting 150 ms. The rest of the analyzed differences failed the level of significance. In reality, the attacks were often recognized in movement stage 2 (flight phase during shortening of the distance), while in VR, they were recognized more often also in movement stage 3 and 4 (landing phase after the flight phase and main phase of the attack). These results are in line with a previous work [22].

We conclude that VR is suitable for applications in sports and also for interventions because we found only a few significant differences in performance between VR and reality. That is in line with a previous study performed by Burns et al. (2011) in which novices were trained in three karate attack types by a real coach, by a video or by a virtual coach. Burns et al. (2011) could also not find any differences between the learning methods and concluded that VR is as appropriate as other methods to reach that novices can learn new and complex movements [16].

We have to mention several limitations of the current study. First, we performed only a pilot study. Therefore, we included only a small number of participants. In future studies, we want to increase that sample size to better draw general conclusions. However, we think that these first results are promising and thus, it is worth the time to include VR technology in training and as method for sports science research.

Table 2. Mean and standard deviation values (mean ± SD) for the parameters response quality and attack recognition, as well as the results of the sign tests. Significant differences between reality and virtual reality are given in bold. Response quality was assessed using a score system (0-2 points) as follows: 0: the responding athlete cannot prevent the attack. 1: the responding athlete can prevent the attack by a block or evasive movement (sometimes followed by a counterattack). 2: the responding attack conducts a successful direct attack. Attack recognition was assessed by back calculation of the given three single reaction times from the first reaction of the responding athlete to analyze the movement stage in which the attack was recognized (movement stage 1-4).

Response quality			
attack	**reality (mean ± SD)**	**virtual reality (mean ± SD)**	**significance**
Gyaku-Zuki	1± 1	0.54 ± 0.81	p=0.124
Kizami-Zuki	1 ± 0.35	0.38 ± 0.7	**z-score=-2.942, p=0.003**
attack recognition			
Gyaku-Zuki 150 ms	2.69 ± 0.72	3.34 ± 0.8	**z-score=-2.971, p=0.003**
Gyaku-Zuki 255 ms	2.17 ± 0.45	2.31 ± 0.63	p=0.581
Gyaku-Zuki 370m ms	1.71 ± 0.46	1.85 ± 0.36	p=0.227
Kizami-Zuki 150 ms	3.2 ± 0.76	3.47 ± 0.79	p=0.115
Kizami-Zuki 255 ms	2.4 ± 0.6	2.71 ± 0.84	p=0.077
Kizami-Zuki 370 ms	1.8 ± 0.47	1.97 ± 0.46	p=0.227

Second, we found a similar kind of response due to the karate attack, but we cannot rule out, that the specific movement execution to reach the desired response movement was different between VR and R. So, it would be important in a further study to analyze the kinematics not only by video analysis but with more precise motion capturing [7].

Third, although we tried to create similar conditions in reality and VR, the attackers were not the same. While in reality the attacker always was a participant of the chosen sample (age 15-18 years, brown belt, 2nd – 1st Kyu), in VR it was a high-skilled male adult of international experience (age 24-58 years, black belt, 1st – 4th Dan). Thus, in VR, the attackers were higher skilled than the attackers in reality, and for the responding athletes it was harder to react in VR compared to reality. In a future intervention, when we increase the sample size, we want to make sure, that the attackers are the same in both conditions. In that future intervention, in addition to the video analysis, we also want to use motion capturing as instrument for movement analysis to examine the movement executions more precisely, and also analyze the existing classification of movement stages more in detail to identify the relevant signals to which athletes respond.

Fourth, we are still not able to identify the correct reaction times, which should be used for distraction from the first measured reaction of the responding athlete to identify the relevant anticipatory signals. Comparisons of the three values showed significant differences between all three reaction times. When subtracting 150 ms, the relevant movement stages were most often movement stage 3 and 4, but when subtracting 255 ms and 370 ms, the movement stages which contain relevant signals were in most cases movement stage 2. Therefore, we can support the results of Petri et al. that the reduction of distance seems to be an important signal to recognize an upcoming attack [19, 22]. As long as the sports specific reaction times in karate kumite are unknown, and as long as no measurements exist to analyze the individual sports specific reaction times, we recommend to further use all the values, which we used from the literature, for studies concerning anticipation and reaction behavior in karate kumite.

5. Conclusion

Based on the data of our pilot study, we found only few differences in the response behavior and in perception of attacks between VR and reality. Therefore, we conclude that applications of VR for training and sports science research are appropriate due to the very similar sports specific behavior. It could be shown that the demand of action fidelity, which was found to be crucial in representative learning conditions to ensure similar behavior in the real and in the simulated condition was fulfilled in the current study. However, further studies, also in different sports, are desirable to confirm our preliminary results.

References

[1] C. Craig, Understanding perception and action in sport: how can virtual reality technology help?, *Sports Technology*, 6 (2014) 161-169. DOI: 10.1080/19346182.2013.855224

[2] R. Gray, Transfer of training from virtual to real baseball batting, *Frontiers in Psychology*, 8 (2017) 1-10. DOI: 10.3389/fpsyg.2017.02183.

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

[4] K. Petri, N. Bandow, & K. Witte, Using several types of virtual characters in sports - a literature survey, *International Journal of Computer Science in Sport*, 17 (2018), 1-48, DOI: 10.2478/ijcss-2018-0001

[5] B. Bideau, R. Kulpa, S. Ménardais, F. Multon, P. Delamarche, & B. Arnaldi, Real handball goalkeeper vs. virtual handball thrower, *Presence*, 12 (2003) 411–421.

[6] N. Vignais, B. Bideau, C. Craig, S. Brault, F. Multon, P. Delamarche, & R. Kulpa, Does the level of graphical detail of a virtual handball thrower influence goalkeeper's motor response?, *Journal of Sports Science and Medicine*, 8 (2009) 501-508.

[7] J. Tirp, C. Steingrover, N. Wattie, J. Baker, and J. Schorer, Virtual realities as optimal learning environments in sport – A transfer study of virtual and real dart throwing, *Psychological Test and Assessment Modeling*, 57 (2015) 57–69.

[8] A.W. De Vries, G. Faber, I. Jonkers, J.H. Van Dieen, & S.M.P. Verschueren, Virtual reality balance training for elderly: similar skiing games elicit different challenges in balance training, *Gait & Posture*, 59 (2018) 111-116. DOI: 10.1016/j.gaitpost.2017.10.006

[9] P. Plummer, Gait and balance training using virtual reality is more effective for improving gait and balance ability after stroke than conventional training without virtual reality, *Journal of Physiotherapy*, 63 (2017) 114. DOI: 10.1016/j.jphys.2017.02.010

[10] F.D. Rose, E.A. Attree, B.M. Brooks, D.M. Parslow, P.R. Penn, & N. Ambihaipahan, Training in virtual environments: transfer to real world tasks and equivalence to real task training, *Ergonomics*, 43 (2000) 494-511.

[11] J.M. Anglin, T. Sugiyama, & S.-L. Liew, Visuomotor adaptation in head-mounted virtual reality versus conventional training, *Scientific Reports*, 7 (2017) 45469. DOI: 10.1038/srep4546

[12] K. Petri, C.-D. Ohl, M. Danneberg, P. Emmermacher, S. Masik, & K. Witte, Towards the usage of virtual reality for training in sports, *Biomedical Journal of Scientific & Technical Research*, 7 (2018b) 1-3. DOI: 10.26717/BJSTR.2018.07.001453

[13] J.A. Stone, B.W. Strafford, J.S. North, C. Toner, & K. Davids, Effectiveness and efficiency of virtual reality designs to enhance athlete development: an ecological dynamics perspective, *Movement & Sport Sciences - Science & Motricité*, 102 (2018) 51-60. DOI: 10.1051/sm/2018031

[14] K. Petri, S. Masik, M. Danneberg, P. Emmermacher, & K. Witte, Possibilities to use a virtual opponent for enhancements of reactions and perception of young karate athletes, *International Journal of Computer Science in Sport*, 18 (2) (Special Edition) (2019b) 1-14. DOI: 10.2478/ijcss-2019-0011

[15] R. Gray, (2019). *Virtual environments and their role in developing perceptual-cognitive skills in sports*, In A.M. Williams & R.C. Jackson (Eds.) Anticipation and Decision Making in Sport, 2019. DOI: 10.4324/9781315146270-19

[16] A.-M. Burns, R. Kulpa, A. Durny, B. Spanlang, M. Slater, & F. Multon, Using virtual humans and computer animations to learn complex motor skills: a case study in karate, *BIO Web of Conferences*, 1 (2011) 1-4. DOI: 10.1051/bioconf/20110100012

[17] J. Petit, & H. Ripoll, Scene perception and decision making in sport simulation: a masked priming investigation, *International Journal of Sport Psychology*, 39 (2008) 1-19.

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

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

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

[21] E. von Oehsen, (1984). *Aufnahme und Verarbeitung bewegungsinitiierender Information für situations- und zeitgerechtes Verhalten - Angriff und Konter im Karate [Perception and Processing of movement initiating information for adequate reaction – attack and counterattack in karate]*, Dissertation [doctoral thesis], university Bremen, Germany] Bremen, Germany.

[22] K. Petri, N. Bandow, J. Binder, M. Droste, & K. Witte, (2018a), Antizipation im Karate-Kumite [Anticipation in karate kumite]. In I. Fichtner (Hrsg.), Technologien im Leistungssport 3: Schriftenreihe für Angewandte Trainingswissenschaft, 13, 74-88. *Aachen: Meyer und Meyer*. ISBN: 978-3-8403-7628-3.

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Conflict of interest

None of the authors have any conflicts of interest to declare.

Informed consent

All participants gave written informed consent to participate in this study.