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Original Article

Immersive training for movement sequences: The use of 360° video technology to provide poomsae training in Taekwondo

PHILIPP ROSENDAHL[1], MARKUS KLEIN[2], INGO WAGNER[3]
[1,3] Institute for School Pedagogy and Didactics (ISD), Karlsruhe Institute of Technology, GERMANY
[2] Institute of Sports Science, Saarland University, GERMANY

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Abstract
Background*:* The use of video technology is an established method of training. As an extended video format, 360° videos expand the potential of conventional videos with immersive and interactive design possibilities and combine conventional video technology with immersive technologies in a resource-saving manner. In sports, 360° videos can be used as tactical training tools to support reflection and analysis and to illustrate movements. In particular, 360° videos can be used to create a recorded authentic learning environment to support observational, multi-perspective training. ***Approach:*** This paper presents the use of 360° video training for the observation and imitation of movement sequences in poomsae training in taekwondo (or kata training in karate), using the example of the Taegeuk II Jang poomsae. The successive four-step concept can not only be applied to poomsae training in Taekwondo, but can also be transferred to other predefined movement forms and choreographies. ***Purpose:*** By using playback media with different degrees of immersion, the movement sequence can be observed, imitated, and followed in successive steps to enable the feeling of participating in a digital training group. ***Conclusions:*** The possible applications of 360° video technology in sports are versatile and offer new, immersive possibilities for simple and accessible training design. Training processes that are predominantly done through observational and imitative learning can be accompanied or shifted to home training with the presented 360° video training concept. In particular, 360° videos are suitable for reflective and observational training due to the multiple perspectives provided by the 360° view, which remain to be evaluated.
Key Words*:* **360° video, digital motion learning, digital training, immersive technology, poomsae, taekwondo**

Introduction

Conventional videos are an established training tool thanks to the visual representation of complex dynamic movement sequences (Saurbier, 2017). Countless publicly accessible training videos of various movement patterns serve as exemplary presentations of optimal movement execution and enable independent familiarization with movements and movement sequences through observation (Fischer & Krombholz, 2020).
Immersive technologies such as virtual reality (VR) enable, on the one hand, a three-dimensional presentation of movement, and on the other hand, repeatable training opportunities in a protected learning environment (Jensen & Konradsen, 2018) and are already being used in a variety of ways in sports (Le Noury et al., 2022), for example, for reaction training and attention enhancement in karate (Petri et al., 2019a, 2019b). VR applications can also be used for observational teaching/learning processes to deepen knowledge and improve movement execution (Petri et al., 2019d).

However, the required technical and financial resources make the implementation of VR applications in sports costly (Fischer & Krombolz, 2020), for example, due to the need for programming skills. On the other hand, 360° video technology is a resource-saving, immersive-interactive technology that combines the advantages of conventional videos with immersive and interactive application possibilities for multi-perspective reflection processes (Rupp et al., 2019, Wesner et al., 2020) without requiring elaborate design skills. For example, with 360° videos, motion sequences can be observed more precisely, and with the help of immersive output or playback media, physical training can take place simultaneously with observation.

Publicly accessible training videos of taekwondo poomsae and karate katas that present movement sequences can be viewed on video portals such as the official YouTube channel of the German Karate Association. However, to the best of our knowledge, 360° videos have not yet been used as training tools to allow observation and imitation in poomsae or kata training. Three hundred and sixty degree videos open up new digital avenues for content delivery and instruction. To utilize 360° video technology as a training tool for movement learning and to demonstrate its advantages, a four-step concept for the digital training of the Taegeuk II Jang poomsae is presented, which is transferable to other predefined movement sequences.

Corresponding Author: PHILIPP ROSENDAHL, E-mail: philipp.rosendahl@kit.edu

Clarification of Terms

Immersion can be described as a feeling of presence and reality within a digital world (Petri & Witte, 2018). However, the concept of immersion also has a technical component, which characterized the output and playback functions of an application (Dörner at al., 2019). These two definitions are used differently in the literature; thus, a clear definition of the term "immersion" is lacking.

The definitions of different immersive-interactive technologies complement each other and make it difficult to find a uniform conceptual definition (Kavanagh et al., 2017, Dörner et al., 2019). However, despite the different ways of defining immersive-interactive technologies, they share several technological characteristics (Dörner et al., 2019). Programmed VR applications enable interactive manipulations of action and can be systematized according to the output media used and their degree of immersion (e.g., Petri & Witte, 2018). Both VR and 360° videos can be experienced with the lowest degree of immersion on a computer desktop by mouse movement or can be highly immersive using head-mounted displays (HMD) such as VR headsets, which provide gaze direction control by head movement, allowing users to feel as if they are really in a programmed digital environment and to interact with this environment (Le Noury et al., 2022).

As an intermediary between video format and VR application, 360° videos enable an individually controllable panoramic view around a given static or dynamically moving camera position during playback (Hebbel-Seeger, 2018). While the recording focus of the camera and the associated viewing direction are individually controllable, manipulation or control of the recorded action is not possible as it is with programmed VR scenarios (Le Noury et al., 2022, Bäder & Kasper, 2020).

In this article, form (poomsae) training in the Korean martial art taekwondo is used as an example. The term taekwondo has existed since 1955 (Moenig, 2015), and the origins of this martial art are found in Japanese karate (Moenig et al., 2014). Since taekwondo has existed, different conceptions of form running have developed. For example, the originator of taekwondo, Choi Hong Hi, based on his experiences with Shotokan karate, initially developed a system that included 24 so-called hyeong (형) (predefined movement patterns), which were later renamed teul (틀), for the International Taekwondo Federation (ITF). Later, the World Taekwondo Federation (WTF, renamed World Taekwondo in 2017) developed a new form system, which currently consists of 17 so-called poomsae (품새).

360° Videos as Training Tools

Digital media are said to have great potential to support teaching/learning processes in sports (Wendeborn, 2019), but this potential has been the focus of little research to date (Zühlke et al., 2020; Vogt et al., 2019). Conventional videos are used in the sports context as a tool for reflection on and analysis of athletic performance or to illustrate movement and technique (Hebbel-Seeger et al., 2013). In contrast to static images, the use of video technology is particularly suitable for representing the dynamics of movement (Dober, 2019). Through different recording perspectives, the targeted optimal movement patterns of role models can be observed, which serve as exemplary movement presentation (Fischer & Krombholz, 2020) with which the trainee can seek to align their own movement, for example, through self-recording and video feedback (Hjort et al., 2018). The multiple training benefits of conventional videos are enhanced by 360° videos to include interaction, immersion, reflection, and analysis (Rosendahl & Wagner, 2022). The 360° view allows motion sequences to be observed from different viewing positions, providing opportunities for multi-perspective observation, for example, in the 360° Pythagoras motion analysis system (Büning & Wirth, 2020), thereby enabling a deeper understanding of motion.

Using immersive output media, 360° videos can also be accompanied by physical activity (Hebbel-Seeger, 2017, Farley et al., 2020), providing not only passive observational training but also active imitative movement learning in a resource-efficient manner. Depending on the desired level of immersion and the quality requirements, 360° video cameras are available for as little as €100. With the use of a conventional smartphone in combination with a Cardboard as HMD, immersive training possibilities can be implemented for observational and imitative poomsae or kata training, providing the feeling of active participation in a digital training group.

Rosendahl and Wagner's (2022) systematic review highlights the diverse uses of 360° videos in sports. This technology is already being used sporadically and exploratively as a cognitive training tool for attention enhancement (Kittel et al., 2020), for multi-perspective reflection on and analysis of game situations and athletic performance (Panchuk et al., 2018), for mental preparation for competition environments (Appelbaum & Erickson, 2016), and for motivation enhancement in sports (Hebbel-Seeger, 2017). In a concept paper, Rosendahl & Wagner (2021) provided a concept idea for the use of 360° videos as an approach to teaching/learning predefined movement sequences in sports. However, to date, there has been no in-depth conceptual analysis of the use of 360° video technology to support teaching/learning processes in martial arts, although some research on immersive-interactive technologies, such as VR in karate, has been conducted (Petri & Witte, 2018, Petri et al., 2019a, 2019b, 2019c). The Kuro-Obi World channel on the YouTube video platform provides a 360° video recording of the karate kata "Heian Shodan" (Kuro-Obi World, 2017). However, this video does not highlight the use of 360° video technology specifically as a training tool. Although other 360° videos with different disciplinary focuses are showcased on YouTube (MDV Communication, 2016), these could be considered in general to be technical gimmicks for the purposes of marketing.

Learning Forms (Poomsae) through Observation and Imitation

In this paper, we focus on forms in taekwondo, which are sequences of pre-determined movements with different hand and foot combinations that symbolize fights against several (imaginary) attackers. To learn a new form, it is first necessary to acquire the repertoire of individual techniques (stances, hand techniques, foot techniques, etc.). Once these isolated techniques are mastered, the sequence (movement pattern) of turns and steps, etc. is gradually worked out. Different methods can be used to do this. Often, the trainer first presents the complete form to the training group. The trainees then enact the form in its entirety, with the trainer giving the command to run movement by movement and the learners following these commands step by step. Afterward, the trainees practice key sequences separately. Finally, the sequences are combined, and in the last step, the trainees run the form without any input from the trainer. Another approach is to learn the form sequentially, starting with the first movement, adding the second movement, the third, and so on, and gradually building up the entire sequence of the form. Again, in the final step, the trainees perform the form from beginning to end without any input from the trainer.

Both methods of learning/teaching lead to trainees mastering the sequence of a new form. Only then does the detailed work begin, including refining the tempo of the movement combinations and increasing the fluidity of the movements with their respective transitions and connections. In East Asian martial arts, techniques are predominantly taught by demonstration and imitation. Therefore, the use of 360° videos to present the movement sequences is a very welcome addition to the training process, especially in the teaching/learning of a new poomsae.

The Taegeuk II Jang Poomsae

The implementation of a 360° video teaching unit for movement learning is shown by using the example of the Taegeuk II Jang poomsae (Fig.1). This approach can generally be transferred to other poomsae.

In the first poomsae, Taegeuk II Jang, two stances, four hand techniques, and one foot technique are taught (Kang & Song, 2007). The hand techniques include three blocking techniques at the three predefined height levels—the lower level (arae), the middle level (momtong), and the upper level (olgeul)—as well as the straight fist punch (both the equal and mutual variants) at the middle level. The two stances include the short forward stance (apseogi) and the deep forward bending stance (apgubi). As a foot technique, the frontal snap kick (apchagi) is taught. Thus, this first form offers a comprehensive repertoire of movements at three height levels, along with defensive and offensive measures and hand and foot techniques without, however, overtaxing the novice trainee.

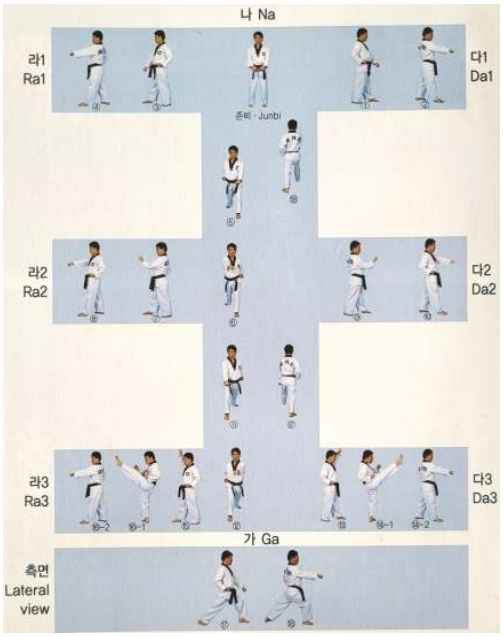

Figure 1: Taegeuk II Jang (Kukkiwon, 2005, p. 314)

Methods

Concept

The presented concept idea focuses on the observation and imitation of predefined movement sequences and can be used for poomsae training in taekwondo (and kata training in karate). Following Bandura's model of learning (Bandura, 1966, 2008), the targeted sequence of movements is presented in a 360° video format by role models whose sequence of movements is independently acquired by learners in three stages that involve increasing immersion and activity levels; in these stages, the learner first observes, then imitates, and finally synchronously produces the movement sequence along with the models.

The concept idea is based on a flipped classroom approach; that is, trainees first watch the movement sequence at home before practicing it in the context of face-to-face training. In contrast with conventional training videos for taekwondo, which predominantly show the movement sequences of poomsae from only one perspective, 360° video training enables a multi-perspective view of the movement execution. To create the multi-perspective view, four role models are positioned in the shape of a rhombus, with the video camera positioned at the center of the formation (Fig.2); the role models perform the sequence of movements as synchronously as possible. This schematic recording design remains the same during the three stages of the 360° video training. Due to the rhombus shape, the movements and step sequences can be viewed from both frontal and sagittal perspectives. From the different viewing perspectives, hip and pelvic movements or joint positions can be highlighted, which is helpful for the acquisition of the movement sequence and allows for a more precise understanding of movement and techniques (Fig.3).

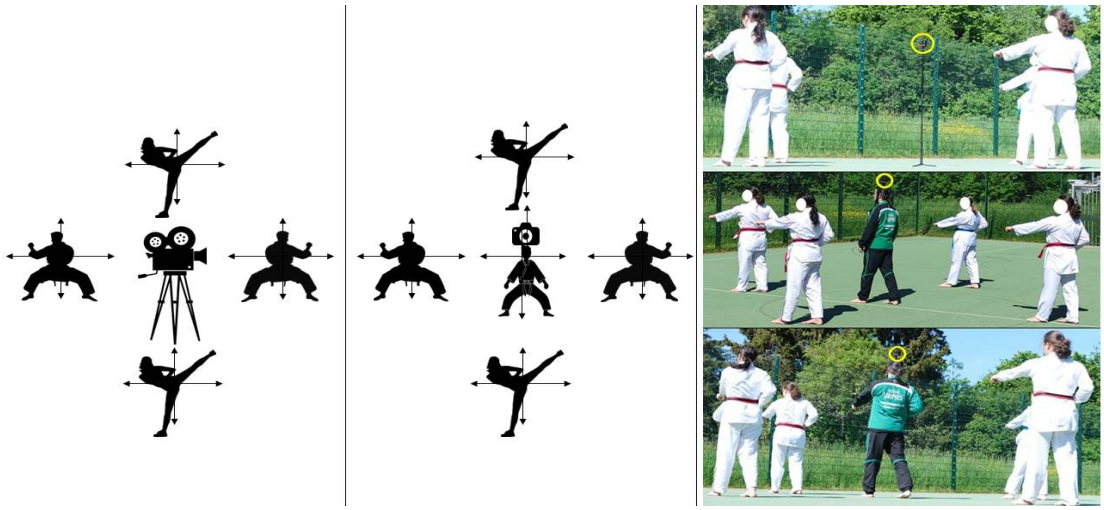

Figure 2: Design with static (1) and dynamic (2) 360° video camera movements and (3) camera position during the 360° video recordings

The first step is independent observation of the 360° video recording. The observation can be done in a low immersive way via desktop control and does not require immersive playback media, such as a head-mounted display (HMD). In combination with interactive observation tasks (e.g., created with H5P software), observation foci can be highlighted within the video recording for a deeper understanding of movement.

In the second step (imitation of the sequence of movements) and the third step (consolidation of the poomsae), immersive playback media, for example, a smartphone with a Cardboard, are necessary to allow simultaneous physical movement with playback of the 360° video footage.

The fourth step, which takes place in the context of face-to-face training, focuses on technique refinement and detailed movement execution. Trainees have already independently learned the step and movement sequences of the poomsae, so time resources can be used for time-optimized movement work and refinement.

Three hundred and sixty degree video recordings can be created for conventional poomsae training without large investments of time or money. Since 360° video cameras allow an all-round view around the camera location, knowledge of camera movement is initially secondary, so the relevant action always remains within the 360° camera focus. Depending on the camera brand, easy-to-use apps exist for post-processing, with which the 360° videos can easily be uploaded to common video portals such as YouTube.

Figure 3: Viewing perspectives in a 360° video recording in panoramic view (lower picture)

Results

Procedure

Step 1 – Observing and Acquiring: The first training step comprises independent observation of the Taegeuk II Jang poomsae, which is performed by the role models at a slow pace. The 360° video recording is done with a static camera positioned at head or shoulder height in the middle of the rhombus formation so that the viewing plane matches the recorded role models. The trainee has the task of independently learning the techniques and sequence of movements of the poomsae by observing. It is a good idea to supplement the 360° video recording with observation tasks and audio explanations running in parallel, first, to guide the focus of the trainee's gaze on the role models and to counteract spatial disorientation, and second, to link several sensory channels and stimuli with each other. Before undertaking the second step, the trainee should be familiar with the sequence of movements and the movement techniques of the poomsae. Below, the possible observation potentials of the 360° video recording are described by focusing on several movement sequences in the Taegeuk Il Jang poomsae.

The poomsae begins with the parallel stance (kibbon chunbi seogi), in which the left foot is placed to the left in the short forward stance (apsoegi) (quarter turn to the left) and, at the same time, a forearm outward block is executed with the left arm at the lower level (arae makgi). This is followed by a forward step with the right foot, also in the short forward stance, with an equilateral fist punch at the middle level (montong pandae chirugi). In the 360° video, thanks to the all-round view and the rhomboid formation, the correct arm movement in both the defense and attack techniques with the corresponding upper body movement can now be viewed from the front and the side as well as from behind, depending on the model being observed.

This is followed by a change of direction with a half turn to the right by placing the right foot in the opposite direction in the short forward stance. This is followed by an outward forearm block with the right arm at the lower level. In the 360° video scenario, the foot positions of the rotation can be repeatedly observed from different viewing perspectives. This is followed by a forward step with the left foot in the short forward stance with an equilateral fist strike at the middle level. Then, another change of direction occurs, this time a quarter turn to the left. Now, the left foot assumes the deep forward bending position (abgubi). This is followed by a hand technique combination in quick succession, namely, a forearm outer side block outward at the lower level (left), followed by a mutual fist punch at the middle level (momtong baro chirugi, right). In the 360° video recording, in addition to the correct foot position, the corresponding hand movements can be repeatedly analyzed from different viewing perspectives.

It can be seen that, in the first step, several observation possibilities are provided by the 360° video recording. This is helpful both for becoming familiar with the movement sequences and for gaining a deeper understanding of the technique through a detailed demonstration.

Step 2 – Imitating and Practicing: The second step in the training involves independent practice of the sequence of movements with an immersive playback medium. By adding a head-mounted display (VR headset or smartphone with a Cardboard), the trainee can control the direction of the 360° video camera.

The poomsae are now recorded using dynamic camera movements, where the video camera is mounted on the head of a fifth model, who is positioned in the center of the rhombus and who moves with a time delay according to the corresponding directions of movement of the poomsae and the other models. Depending on the 360° video camera brand, various mounts exist for dynamic camera movements; for example, an action camera can be attached to a bicycle helmet to record a dynamic video that gives observers the perspective of the person recording.

In this step, the 360° video camera position maintains an all-around view of the role models and provides a choice of perspective on the sequence of movements. The trainee can thus continue to observe the techniques of the four role models from the center of the rhombus in a multi-perspective manner and subsequently imitate them.

The dynamic offset camera movement, in combination with observation by an HMD, enables the trainee to imitate the movement sequence of the poomsae. First, the movement execution in this poomsae with the turn to the left in apsoegi with simultaneous arae makgi is performed by the models, who remain in position briefly after executing these movements. Subsequently, after a command signal, the central model moves in the 360° video recording according to the direction of movement of the models. Only after that, the models of the rhombus formation perform the next technique ("apsoegi" with "montong pandae chirugi") with subsequent imitation of the fifth model within the 360° video recording. This repetitive process is maintained in the second step. In this way, the trainees are first shown the movements and then given an opportunity to imitate them. In addition to observing the movements, the goal of the trainees is now to physically move after the command signal and to imitate the techniques. Due to the higher immersion level achieved with the head-mounted display, the trainees feel like they are in the position of the camera, and they become part of this digital training group. In addition, audio cues or digital movement cues can be given to accompany and guide the movements to be imitated.

Step 3 – Performing and Consolidating: In the third 360° video recording, the models increase the speed, fluidity, and force of the poomsae techniques while they maintain their formation in a rhombus shape. In contrast to the staggered dynamic 360° video camera movements in step two, in this recording, the fifth model in

the middle of the rhomboid formation now performs movements synchronously with the movements of the other models. To facilitate this synchronicity, counting commands are given. These commands also support the synchronous co-movement of the trainee so that the movement to be executed corresponds to the digital direction of movement of the video camera guidance in the video recording.

Step 4 – Refining and Applying: The fourth step of the 360° video training concept takes place in the context of face-to-face training. With the help of the three 360° video recordings in the first three steps of the training, the trainees have independently acquired the basics of the Taegeuk II Jang poomsae. They have learned the sequence and direction of the movements of the poomsae and can implement them in a rough form. In the fourth step, face-to-face training time is used to refine and optimize the techniques by focusing on movement intensity and the detailed execution of the movements of the poomsae.

Discussion

The 360° video training concept offers a simple and resource-saving immersive training option for efficient poomsae training in taekwondo. As an enhanced video format, 360° videos take advantage of conventional video technology while extending it to provide an immersive training experience with opportunities for active interaction, consistent with cognitive learning theories such as model learning. Observation and the imitation of movements performed by a teacher are predominantly used in the first steps of teaching poomsae in taekwondo; the use of 360° videos is compatible with this approach and opens up new time- and cost-saving training possibilities. These training possibilities can be transferred beyond martial arts to other predefined movement forms, where movement sequences, e.g. of choreographies, are initially acquired through observation, demonstration and imitation. Time-optimized, the step sequences can be worked out independently in order to use face-to-face training times for refinement and optimization.

The possible uses of 360° videos for reflective or cognitive training, which have been demonstrated in a previous systematic review (Rosendahl & Wagner, 2022), can be adapted to observational and imitative training of predefined movement sequences (Rosendahl & Wagner, 2021), in particular for poomsae training in taekwondo. The four-stage structure with the flipped classroom approach enables learners to independently learn the basic movement sequences of poomsae and then proceed to face-to-face training to refine their movements and technique. The gradual increase in the degree of immersion and activity over the course of the first three steps of the 360° video training reduces the risk of motion sickness. With the use of immersive playback media and dynamic 360° video camera movements, visually perceived movements may not correspond to real-life movements, thus triggering discomfort (Hebbel-Seeger et al., 2019). Therefore, it is important that, in the first step of the training, trainees learn the sequence of movements with the initial observation-only task and a static 360° video camera position. In the second step, the dynamic 360° video camera movement is offset in time to the movements of the models and the trainees are shown the movement sequences again by the recorded models, which they then imitate. It is only once the trainees have learned the sequence of movements of the poomsae that the recorded movements of the role models are executed synchronously with the dynamic 360° video camera movement; this design is intended to prevent motion sickness as far as possible.

Conclusions

The possible applications of 360° video technology in sports are versatile and offer new, immersive possibilities for simple and accessible training design (Rosendahl & Wagner, 2021). In particular, 360° videos are suitable for reflective and observational training due to the multiple perspectives provided by the 360° view. The use of 360° videos for the observational and imitative training that constitute the first steps in learning a poomsae or kata can be used in combination with immersive playback media to make the most of face-to-face training time to refine trainees' technique.

In addition, previous studies on 360° videos as a training tool have identified motivational potential with 360° video technology. However, the reported motivational effects may be due to the perceived novelty of the 360° video training experience by learners with no prior experience (Kavanagh et al., 2017). Likewise, general conclusions about training success are premature, as most studies tend to have exploratory research designs (Rosendahl & Wagner, 2022). Therefore, the next step is to investigate the motivational effects of 360° video training as well its training success and benefits. Future studies could extend the research to additional poomsae or katas, that is, ones that involve more techniques, directions, and movement variations as well as higher difficulty levels. Furthermore, it would be interesting to examine the effectiveness of the method as a function of the training experience. For further discussion and research of 360° videos as a teaching–learning medium, it is also advisable to use the term clearly and distinguish it from VR. In particular, 360° videos are also distinguished from virtual reality by their ease of design and use.

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Conflicts of interest: The authors declare that they have no competing interests. There are no financial or other relationships that might lead to conflicts of interest.

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Graphics:

free to use vector graphics on pixabay.com