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Article

Visualization of Motion Image by Humanoid Input Device for Shooting Motion in Basketball and Its Effectiveness

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Abstract
The use of imagery is effective for the acquisition of sports movements. However, the details of recalled images have not yet been clarified. Therefore, the purpose of this study was to visualize the image of a basketball shooting motion using a humanoid input device. We also aimed to clarify the effects of such visualizations on the formation of the players' movement images and the understanding of their movement skills. Six elite female athletes belonging to a professional team and six high-school female athletes who had participated in national tournaments were selected as participants, and motion images were created using a humanoid input device. The results of the analysis indicated that the detailed reproducibility of the motion images and the relationship between the individual movements and the whole movement differed according to the proficiency level of the shooting movement. In addition, it was suggested that in the acquisition of the shooting motion, the promotion of metacognitive activities for one's own motion enhances the analytical and individual sensory understanding of the motion, as well as the formation of an image that relates the whole motion.

Keywords: Movement Imagery, Reflection, Metacognitive Activities.

1. Introduction

The acquisition of sports movement skills is called "sensory-motor learning," which involves a cooperative relationship between the sensory and motor systems and follows a process of mastery from the trial-and-error stage, through the regulation stage, to the automatic stage (Yamada et al., 2021). Kitamura (2011) highlighted the importance of athletes understanding the sequence of movements and expressing it as an overall series of natural movements after connecting their understanding with their own senses in the acquisition of sports movements. The key to this is imagery ability. Imagery in sports is defined as the creation or reproduction of experiences generated from memory information containing quasi-sensory, quasi-perceptual, and quasi-emotional characteristics under the control of consciousness (Annett, 1995; Morris et al., 2005). Furthermore, because imagery ability reflects an individual's ability to form, maintain, and transform images, such as vividness and ease (Williams and Cumming, 2011), it can be expected that enhancing an individual's imagery ability will have a positive effect on learning using imagery. In addition to movement acquisition, imagery is used in various situations in sports learning, such as tactical understanding, motivation, and psychological conditioning, and its effectiveness has also been studied. Furthermore, many studies on training using such imagery have been reported, and many have shown that the effectiveness of such imagery can be expected to improve when training methods are devised. For example, Cooley et al. (2013) reported an approach based on the physical, environment, task, timing, learning, emotion, perspective (PETTLEP) model

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(Holmes and Collins, 2001). The PETTLEP model is an imagery training method that takes into account seven factors that should be considered when recalling motor imagery. However, insufficient research has been conducted regarding the effective use of the PETTLEP model (Munroe-Chandler et al., 2012; Dickstein et al., 2004). In addition, images have both a descriptive aspect (the sensory part of the object) and an explanatory aspect (the interpretation or understood meaning of the object) (Miyazaki, 1980). Because images are internal processes, they are difficult to visualize, and their inner reality is difficult to grasp (McAvinue and Robertson, 2008). Therefore, it has been pointed out that the discrepancy between the image that athletes have of their own movements and the actual movements is problematic for them and that the effectiveness of image training is affected by how well or poorly they are doing (Hasegawa and Hoshino, 2001). Thus, because it is difficult to grasp the details of the movement images that players draw, we believe that the visualization of the images is important in the investigation of training using imagery.

Therefore, in this study, we attempted to visualize the motion images drawn by players by reproducing their motion images on a computer using a humanoid input device. The purpose was to examine the influence of such image visualization on players' understanding and acquisition of movement skills.

Because the purpose of this study was to analyze the details of players' experiences in recalling images, we judged that a qualitative research method was appropriate (Kitamura et al., 2005) and adopted it as the methodology.

2. Methods

2.1. Participants

The 12 participants in this study were six high school female basketball players who had participated in a national tournament and six professional female basketball players who belonged to a professional women's basketball team. The 12 participants were classified according to their level of proficiency: 3 high school students as intermediate players (participants A,B,C), 3 high school students as advanced players (participants D,E,F), and 6 professional players as proficient players (participants G to L).

2.2. Procedure

The survey was conducted from October 20XX to January of the following year. Before the survey, the operation of the humanoid input device used in this study was explained. After that, all participants were asked to use the device freely. After it was confirmed that all participants were familiar with the operation method, the survey was started.

2.3. Data Collection: QUMARION

A humanoid input device (QUMARION, manufactured by Celsys, Inc.) was used to record motion images. This humanoid input device operates by manipulating a humanoid model with multiple joints, creating its movements as images on a computer screen. These images can be rotated 360 degrees to view from any angle. The device is equipped with 32 sensors distributed throughout the body. When each part moves, the information is captured in real-time by the PC, allowing users to pose the humanoid image on the PC screen using corresponding 3D animation software. (Figure 1).

First, the participant was asked to reproduce his or her own free-throw motion while manipulating the humanoid input device. In creating the motion video, the participant graded the entire free-throw motion by herself and created a motion video for each point, such as the wrist, head, arm, torso, waist, foot, and entire body. Because the computer images moved in synchronization with the operation of the human input device, the participnts checked the motion and made several revisions, confirming that the images were almost the same as their own motion images, and the video was completed.

2.4. Data Collection: Interview Survey

Data were collected through interviews using the following two methods. First, in the process of creating movement images while operating the human input device, interviews were conducted to confirm the kinds of images being used and how they were expressed for each point, such as the wrist, head, arm, torso, waist, leg, and whole body. The interviews were semistructured in-depth, and open-ended. Next, based on the visualized movement images, we asked the participants what kind of consciousness they had in performing the shooting movement and what kind of body movements they expressed by changing the movement images from various angles, using the stimulus playback method (stimulated recall). In-depth open-ended interviews were conducted in a semistructured manner. In addition, a table was created to show the movements of the computer-generated motion image from four angles (front, back, right, and left) at each stage of the movement. The participants were asked to write reflection notes on the visualized movement images. Based on the notes, in-depth, open-ended interviews were conducted in a semistructured manner

using the stimulus playback method (stimulated recall). Semistructured interviews were conducted in-depth using stimulated recall and open-ended interviews based on the notes. In the notes, the participants were instructed to write down what they considered to be important points, evaluate the reproducibility of the movements, and identify unclear images, areas of concern in their own movements, and good areas of their own movements (Figure 2).

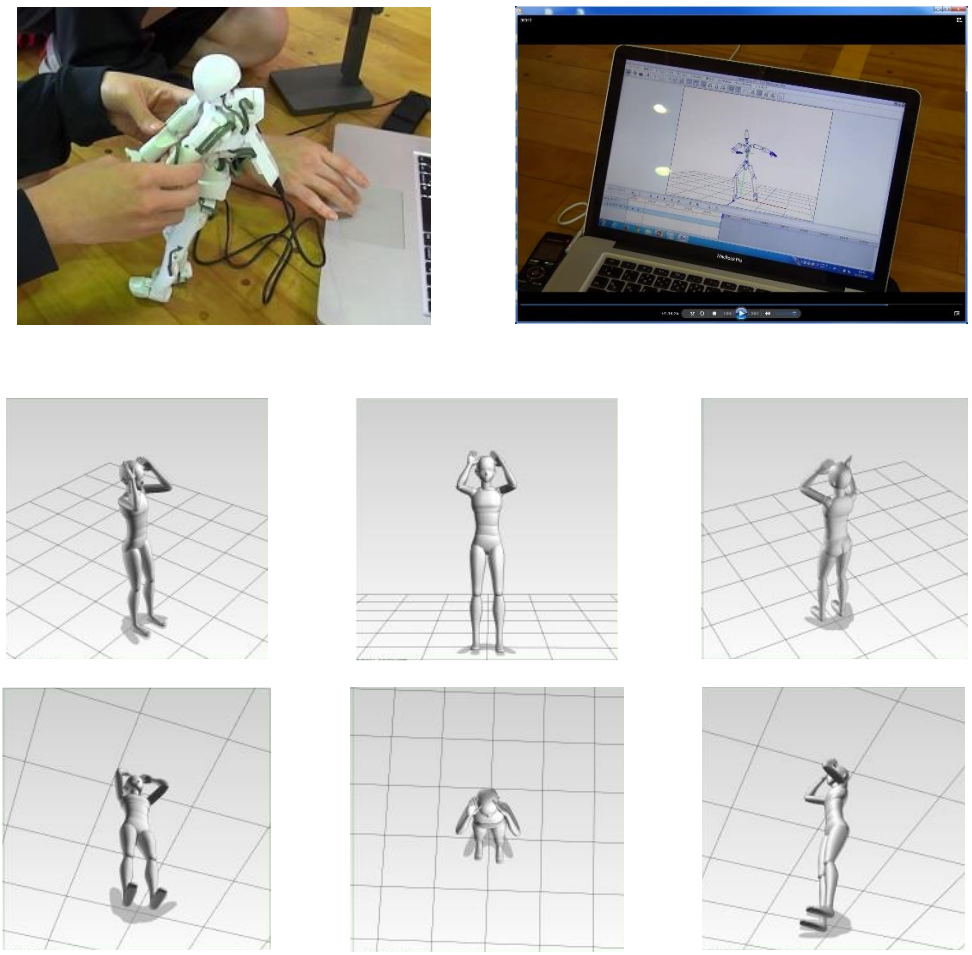

Figure 1. Humanoid input device QUMARION and created images

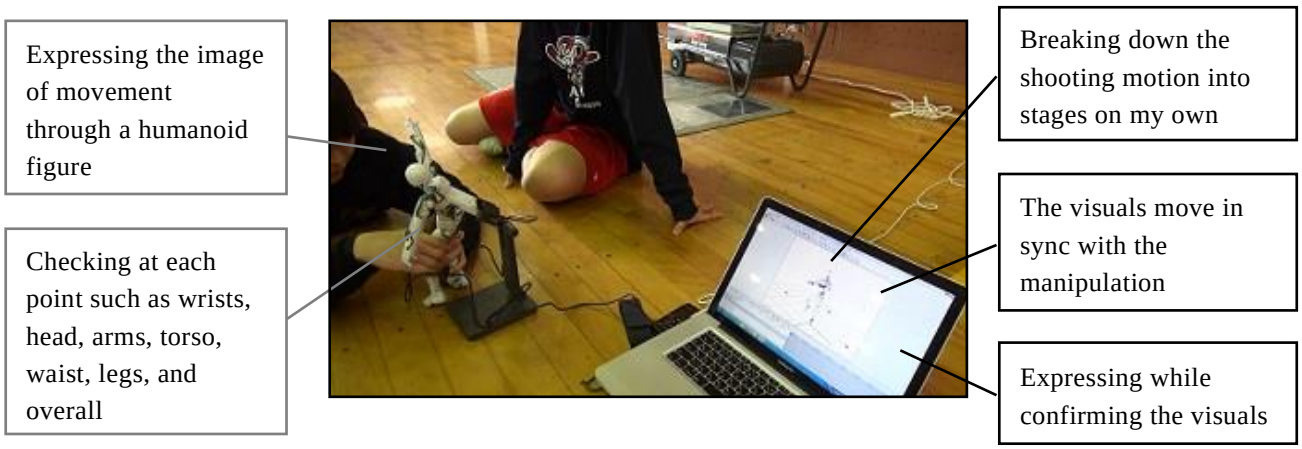

Figure 2. Scene of creating movement imagery

2.5. Data Analysis

The speech data obtained from the interviews were immediately converted into text, and then hierarchical categorization was conducted based on the qualitative data analysis method of Côté et al. (1993) and Patton (2002), with multiple researchers sharing the analysis process.

2.6. Credibility and Certainty

We conducted a study to evaluate the quality of the research based on authenticity (reality of the data) and certainty (whether the data and procedures can be relied upon), as presented below. First, to confirm that the participant's motion image was accurately visualized, we asked the participants to speak while focusing on the key points during the operation of the human input device, which was considered authenticity. Second, to visualize the motion image more accurately, the investigation was conducted in a gymnasium so that the participants could operate the human input device while confirming their actual movements. This enables certainty to be considered. Third, the interviews were conducted in a semistructured manner to ensure the homogeneity of the questions for multiple subjects and to provide certainty in data collection. Fourth, data certainty was ensured by adopting a stimulus replay interview method based on the motion pictures and the motion reflection sheets generated by the participants. Fifth, the process of data analysis was shared by several experts, and the analysis was conducted through multiple discussions to ensure certainty.

3. Results and Discussion

3.1 Motion Images

The participants created their own motion images by dividing the entire shooting motion into several phases (Figures 3–5). Three motion images were created using three groups with three, four, and five motion divisions. Three motion divisions were created by three intermediate high school basketball players (A,B,C), four motion divisions were created by two advanced high school players (D,F) and one proficient professional player (G), and five motion divisions were created by one advanced high school player (E) and five proficient professional players (H to L).

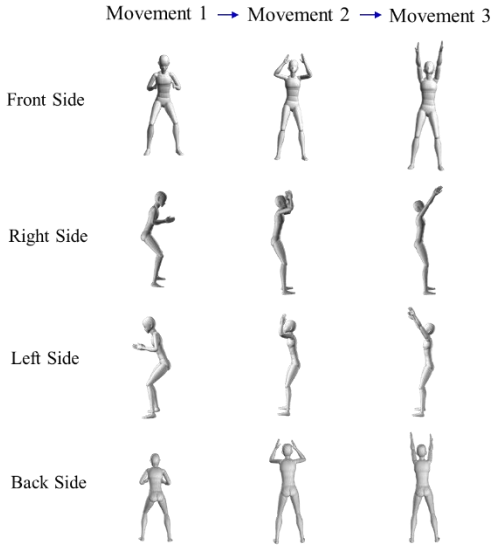

Figure 3. Image of free-throw movement (three motion divisions): Player A

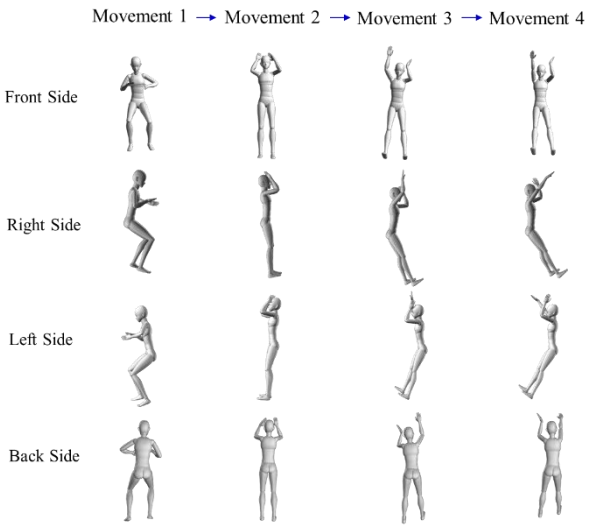

Figure 4. Image of free-throw movement (four motion divisions): Player D

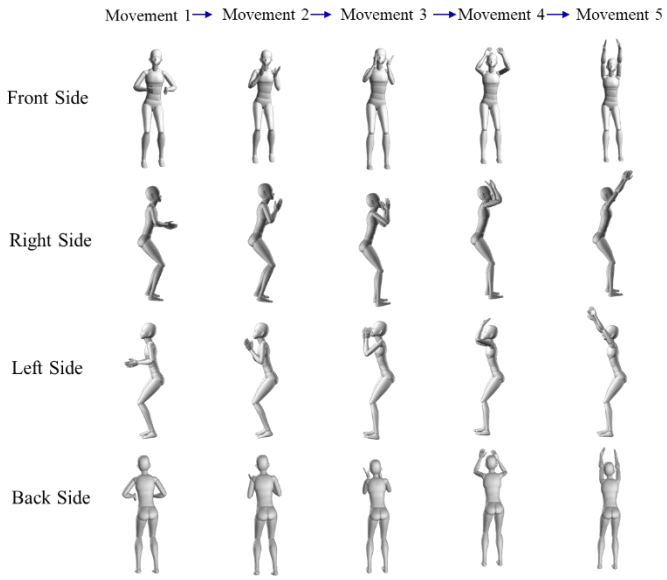

Figure 5. Image of free-throw movement (five motion divisions): Player E

3.2. Motion Image Reflection Memo

In this section, the reflection memo created in the form of writing on the visualized motion image picture is examined.

Figure 6 shows a reflection memo based on the motion image of Player A, who is at an intermediate level of proficiency, with the motion image expressed by dividing the motion into three segments. In the memo, the participant was instructed to write down what she considered important points and areas of concern during her own movements. However, there were few notes on each image, and there were many ambiguous parts in the player's own movement images. The participants were asked to self-assess the extent to which the generated motion imagery accurately replicated various aspects: the shape and position of each body part (spatial elements), the flow of movement (temporal elements), and the specific features of the action (individual elements). Consequently, ambiguous assessments were offered, including expressions such as "it might be," "I believe it resembles something like this," and "slightly leaning forward." Furthermore, comparative evaluations between the actual motion and the generated imagery by other players indicated that while the movements and flow were not perfectly aligned, they were deemed to be quite similar.

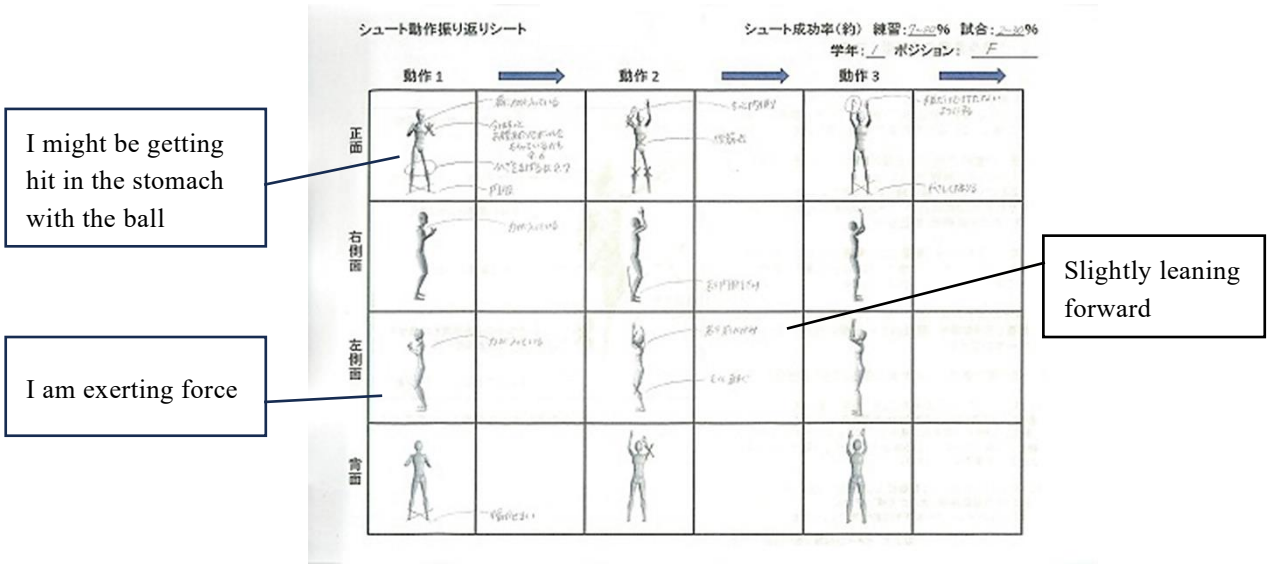

Figure 6. Point review memo based on the motion picture (three motion divisions): Player A

Figure 7 shows the reflection memo of Player D, who is at an advanced level of proficiency, expressing the movement image in the four movement divisions. The memo describes in detail the points of movements that are important to the player and the points of physical movements that she is conscious of in practice and games. In addition, each movement is associated with each of the others, and it can be inferred that the movement image is formed with an awareness of the linkage and flow of the movements. The evaluation was made in an unambiguous manner. Evaluation of reproducibility of action imagery suggests that the participants in all three categories are believed to have a high level of alignment between actual movements and imagined representations. This inference is drawn from statements such as "I think of it as being my true self" and "My movements are reproduced quite accurately," made by all three subjects in this classification. Moreover, descriptions such as "Bringing my right foot forward to avoid arching my body while jumping" and "I always make a conscious effort to keep my right hand in this position" indicate that play is executed with deliberate attention to the body and movements, suggesting a detailed awareness of one's bodily actions. However, expressions like "It might be more internal, if anything" regarding specific details or the state of the body during actual movements suggest that there may be discrepancies between the imagery of actions and the actual sensations experienced during movement. Thus, it can be inferred that there is a possibility that the imagery of actions and the actual movements being felt do not perfectly align.

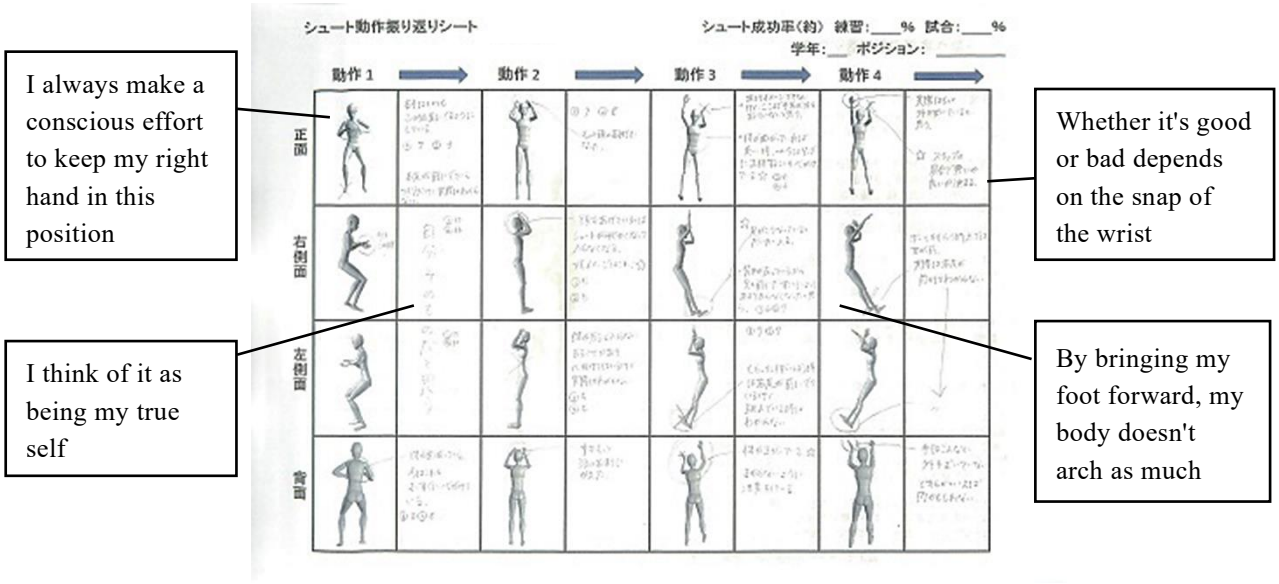

Figure 7. Point review memo based on the motion picture (four motion divisions): Player D

Figure 8 shows the reflection memo of Player E, who is very proficient in expressing the movement image in the five movement segments. In the memo, there are many descriptions of the movements seen from the outside as well as matters seen from the inside and sensory matters felt from the inside. The movement images are handled using both external and internal images. In this group of five divided actions, all players vividly depicted the imagery of shooting movements. Descriptions such as "straighten the body as if pushing the ball up from above the head and extending the knees" and "tighten the buttock muscles, exert firm pressure on the thighs, and synchronize the movements" suggest that they envisioned the sequence of shooting actions while associating them with various bodily movements and gestures. From this, it can be inferred that they possess a high level of self-awareness and perceptual representation formation ability. Furthermore, statements such as "it matches perfectly," "I believe I can express even habits and individuality in detail," and "I feel that not only the form of movement but also the conscious effort to create that form is expressed" indicate that there is minimal disparity between the actual movements and the imagery. Based on the above points, it is believed that the findings support the reports by Tanaka (2000) and Hishitani (1993) , which point out the relationship between the clarity of imagery demonstrated by high levels of self-awareness and proficiency in motor skills. Specifically, it was observed that as proficiency in movement increased, the clarity of imagery improved. This improvement led to an enhanced frequency and capacity to vividly reproduce movements through the body. Consequently, a reduction in the disparity between imagery and actual movements was noted, affirming the relationship between the enhancement of imagery clarity and proficiency. Furthermore, proficient players attribute personal meanings such as habits, strengths, and confidence to their movement imagery, suggesting that cognitive aspects influence movement imagery alongside sensory aspects.

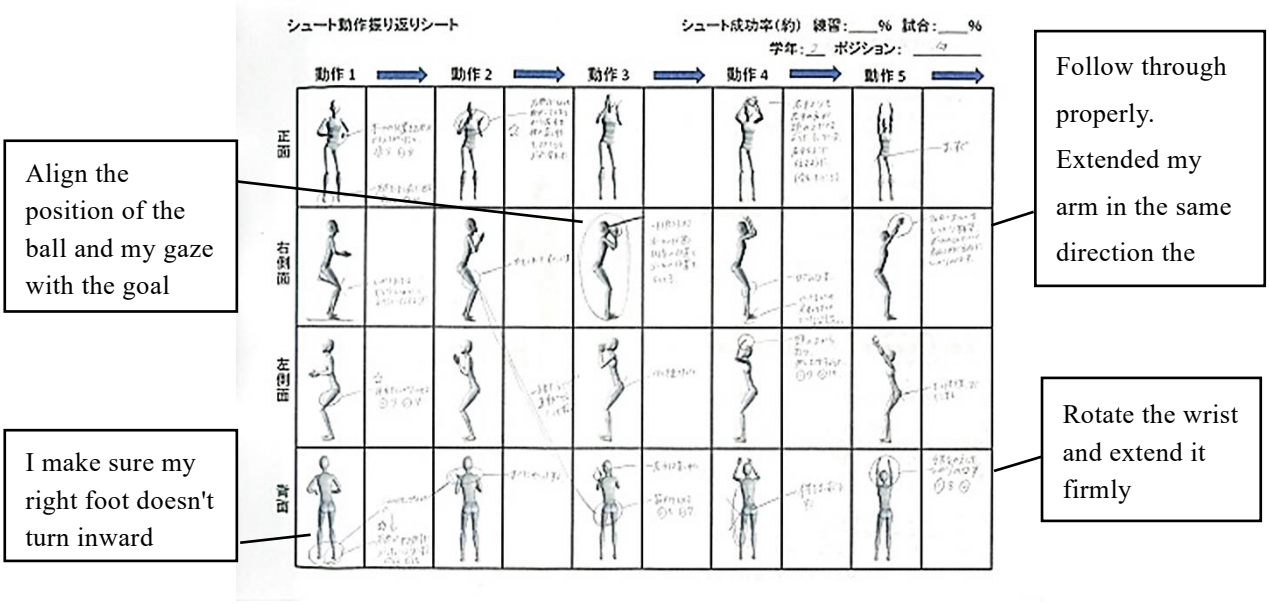

Figure 8. Point review memo based on the motion picture (five motion divisions): Player E

3.3 Analysis of Utterances Related to Action Images

We conducted a qualitative analysis based on the qualitative data analysis method of Côté et al. (1993) and Patton (2002). Specifically, from the textualized utterance data, utterances related to action images were extracted as a single meaning unit, tagged, categorized into subcategories with similar meanings while considering the context of the utterance, and then categorized into subcategories with similar meanings. They were further grouped into categories with similar meanings to create hierarchical categories. The 64 obtained meaning units were grouped into eight subcategories, which were further divided into three categories. Table 1 lists the hierarchical categories.

Table 1. Hierarchical Category and Key Utterance Lists

Category	Subcategory	Speech Example
Confirmation of pre-existing sensations	-Condition of body parts -Good movement awareness -Attention and sensory expression	-I let my wrists flex like this. (L) -I always keep my right hand in this position. (J) -The ball is held in the stomach area. (F)
Check for uncertainties in movement and sensation	-Searching for physical condition -Matching of movement results with kinesthesia	-I don't know what happens below my ankles when I'm jumping. (G) -I don't have a good idea of the direction of my wrists. (C)
Correction of sensory discrepancies	-Confirmation of movement at a bad time -Organize movement awareness -Check movement awareness and sense of movement	-I have a habit of bending my body, and I try to do it, but I don't really know what it is. (D) -When I don't shoot, my knees are not bent, so I have to be careful. (K)

Confirmation of pre-existing sensations

This category was created to describe the confirmation of body positions and sensations while paying attention to each movement. As indicated by expressions such as "*like this"* and *"around here,"* this category shows the awareness of connecting the state of the body part and the sensation being attended to the image of the action, while capturing it descriptively.

One player described the sensation of releasing the ball as follows; *"At the moment of releasing the ball, I throw the ball as if I push it out with my knees. So I don't really feel like I'm making an action with my hands or arms." (Player B)*

Another player, while recalling and checking the positions of her own body parts, described the body parts she is always conscious of as follows: *"I am always conscious of my right hand coming to this one. So I hope I was able to express that part well with this doll." (Player F)*

These statements suggest that by manipulating the humanoid input device to create images, the participants became conscious of the motion images they had previously held vaguely, to focus on the sensations they already had, to confirm them, and to manifest them in an objectively visible form as images.

Check for uncertainties in movement and sensation

This category was created to indicate awareness of the need to explore and check the state and sensation of one's own body in an attempt to express movement images through the manipulation of a humanoid input device. In this category, an attempt was made to explore the movements of specific parts of the body and the accompanying sensations that are unknown. It can be seen that each movement is related to the others and that the entirety and continuity of the movement, such as the movement of the whole and the flow of the movement, are being considered.

One player described this point as follows:
"I have a sense of what it feels like to jump, but after that, I don't really know. I can feel my knees and ankles, but I don't have a clear image of the angle of my ankles, or the order in which the various parts of my body move. I wonder what's going on." (Player D)

Using the senses that she already has as clues, she is trying to become aware of the connections between the senses in areas where the image is unclear, while being conscious of the relationship between the movements. From these utterances, it can be seen that in the process of making the movement image conscious, a conscious activity to search for sensory cues that are not yet present is taking place.

This is because of the meaning of extending the movement image, and it is presumably important in terms of continuity in image formation or the construction of relationships between individual images. In this regard, Kaneko (2020) pointed out the importance of extending body images from the viewpoint of rehabilitation. This process of conscious image creation is also consistent with Naruse's (1988) concept of intention and effort as important concepts in movement imagery. In other words, movement is a process of active activity in which one strives to realize body movement as intended, which is consistent with what the participants in this study described as "*thinking, doing, and then correcting the action over and over."*

Correction of sensory discrepancies

This category was created to indicate an awareness of checking for discrepancies between the actual movement and the sensation of movement by checking the conscious movement in more detail in the image using sensation as a cue.

One player described the discrepancy as follows; *"I have an image of feeling the weight of the ball in the palm of my hand and then putting all my strength into it. But in reality, I throw the ball quickly, so I feel that my image is a little different from what I am actually doing." (Player L)*

Another player recalls images not only from an external image but also from an internal point of view and matches the actual movement with the motion image from the perspective of the motion image felt from the inside: *"When I do not shoot, my knees are always extended, so when I imagine the movement, I draw an image of bending my knees. When I visualize the movement, I imagine my knees bending. This gives the image a three-dimensional feel."* (Player H)

These statements indicate that it is important for athletes to have a movement image from the objectified third-person perspective as well as the movement image from the first-person perspective as the participants in the movement, and the ability to recall the image from both perspectives in the process of creating the movement image leads to a clearer image. The process of creating motion images suggests that being able to recall images from both perspectives leads to clearer images. This point overlaps with that of Yamada et al. (2021), who pointed out that motor images experienced as simulations of actions are important for motor learning.

5. Conclusion

In this study, we visualized the motion images drawn by players by reproducing their motion images on a computer using a humanoid input device. Then, we examined the influence of such visualizations on players' understanding and acquisition of movement skills. The results show that the elaboration of the motion image tended to increase with the degree of proficiency in the free-throw shooting motion. In addition, it was shown that the extension from an individual action to the whole action, relevance, and diversity of the viewpoint of the image also changed according to the level of proficiency. In addition, it was suggested that the effort to visualize the movement image promotes metacognitive activities for one's own movement in the image formation of the chute movement, thereby deepening the analytical and individual sensory understanding of the movement and at the same time promoting the image formation relating the entire movement.

Author Contributions

Conceptualization, K.K. & Y.M; methodology, K.K.; validation, K.K. & Y.M.; qualitative data analysis, K.K. and Y.M.; investigation, K.K. and Y.M.; resources, Y.M.; writing—original draft preparation, K.K.; writing—review and editing, K.K.; visualization, Y.M.; supervision, K.K.; project administration, K.K.; funding acquisition, K.K

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Institutional Review Board Statement

The study was conducted according to the Declaration of Helsinki.

Informed Consent Statement

Informed consent was obtained from all participants involved in the study.

Conflicts of Interest

The authors declare no conflict of interest.

Acknowledgments

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Appendix

Scene of operation image creation

The process of creating an image using a humanoid input device

Operation of humanoid input devices

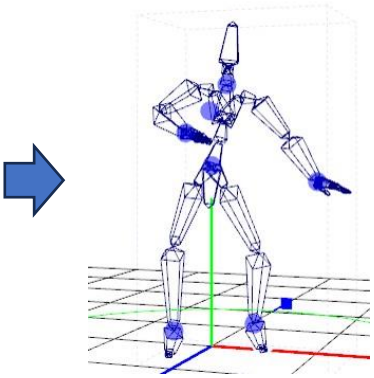
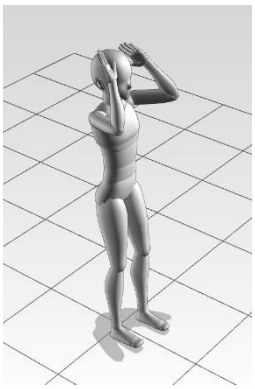


Image of movement created by line drawing



Motion picture with human figure

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