A Study on Cognitive Transformation in the Process of Acquiring Movement Skills for Changing Running Direction

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SUMMARY In ball games, acquiring skills to change the direction becomes necessary. For revealing the mechanism of skill acquisition in terms of the relevant field, it would be necessary to take an approach regarding players’ cognition as well as body movements measurable from outside. In the phase of change-of-direction performance that this study focuses on, cognitive factors including the prediction of opposite players’ movements and judgements of the situation have significance. The purpose of this study was to reveal cognitive transformation in the skill acquisition process for change-of-direction performance. The survey was conducted for three months from August 29 to November 28, 2020, and those surveyed were seven university freshmen belonging to women’s basketball club of M University. The way to analyze verbal reports collected in order to explore the changes in the players’ cognition is described in Sect. 2. In Sect. 3, we made a plot graph showing temporal changes in respective factors based on coding outcomes for verbal reports. Consequently, as cognitive transformation in the skill acquisition process for change-of-direction performance, four items such as (1) goal setting for skill acquisition, (2) experience of change in running direction, (3) experience of speed and acceleration, and (4) experience of the movement of lower extremities such as legs and hip joints were suggested as common cognitive transformation. In addition, cognitive transformation varied by the degree of skill acquisition for change-of-direction performance. It was indicated that paying too much attention to body feelings including the position of and shift in the center of gravity in the body posed an obstacle to the skill acquisition for change-of-direction performance.

key words: cognitive transformation, skill acquisition, change-of-direction performance, coaching

1. Introduction

1.1 Background

In ball games such as basketball and soccer, sprinting is regarded as an important skill making the difference between winning and losing [1]–[3]. Meanwhile, not only sprinting faster but also acquiring skills to change the direction becomes necessary. This is because in these ball games players, for reacting to their opponent’s movements, repeatedly moves to slow down and suddenly stop while springing and then restart in every direction. Therefore, the performance of ball game players is substantially affected by how suddenly they can stop and how fast they can reach their top speed through reacceleration while swiftly changing the direction to avoid objects.

Grindstaff et al. (2006) reported that acquiring rational movement skills for changing the running direction would improve performances and further be useful for preventing sports disorders including knee injuries and troubles [4]. Additionally, Cinelli and Patla (2007) stated that in avoiding an obstacle people would change their moving direction in order not to collide with it while calculating the distance to it and the time needed to change the direction [5]. Pauole et al. (2000) reported that significant differences in mean scores were found as a result of the examination of 304 college-aged men and women varying in the level of sports participation for the relationships between their time of 40-yd dash and that of a hexagon test for agility [6]. In the meantime, it was pointed out that movements to change a running direction was affected by cognitive factors such as visual-scanning techniques and visual-scanning speed [7]. For instance, Young et al. (2002) showed that the relationships between leg muscle power and change-of-direction speed were not consistent and also pointed out that technical and perceptual factors having some importance in change-of-direction performance should be considered [8].

1.2 Research Approach to Change-of-Direction Movement

Considering the accumulation of academic researches mentioned above, while it is thought to be necessary to make discussions through approaches from various perspectives to pursue the mechanism of change-of-direction movements, many of the research approaches to change-of-direction movements are consistent of those analyzing performances that can be observed from outside [2]–[6]. This approach is positioned as the core of biomechanics that explores skills from mechanical aspects and its basic stance is to analyze assessable performances based on objective values [9].

No one will take objection to the effectiveness of an approach to deal with physical movements that can be evaluated objectively. However, physical movements that can be measured objectively are not enough to fully understand the acquisition of skills. Specifically, under sports settings, it is common for people to understand in their mind what has been explained based on numerical data measured objectively but not to be entirely convinced by it. Sheppard and Young (2006) recommended an approach from the aspects of both movement and cognition as a new evaluation regarding change-of-direction performance [7].
It is true that the cognition of skill acquisition is a subjective view generated through various processes including independencies on the conditions of environments (situated cognition)\[10\], as well as the physicality, muscles, body strength and further physical abilities of each individual (individuality of physical characteristics). In the meantime, in actual sports coaching, it becomes important to match players’ evaluation on their movements with cognition as far as possible. Especially, in the phase of change-of-direction performance that this study focuses on, not only the properness of body movements but also cognitive factors including the prediction of opposite players’ movements and judgements of the situation have significance. From such a perspective as well, for revealing the mechanism of skill acquisition in terms of the relevant field, it would be necessary to take an approach regarding players’ cognition as well as body movements measurable from outside.

1.3 Research Question

From the perspective of cognitive science, efforts based on brain reactions have been made as an approach to clarify the mechanism of human cognition in the relevant field\[11\]–\[14\]. Meanwhile, it has to be remembered that while these studies can deepen the understanding of human physiology study participants practicing skills cannot recognize that their brain reacts. Therefore, it is thought to be difficult to apply the knowledge on how their brain is functioning to actual coaching. Particularly, in seeking cognition in the process for acquiring skills which this study focuses on, there is a limit as a research approach to having research participants scheduled to do intense exercises wear the equipment to measure their brain activities.

Thus, in order to obtain knowledge that can be applied to actual sports settings, it would be useful to, rather than focusing on non-conscious processes like brain activities, make discussions focusing on a conscious one such as how players have felt and thought\[15\]. After all, for seeking the conscious process of a player practicing exercises for acquiring skills, depending on words from a player is the only way.

Now, regarding the approach to focus on players’ languages, it is quite possible that the characteristics of a language such as ambiguity, similarity and polysemy make it difficult to conduct quantitative analyses and that their cognition of languages itself originally inhibit the acquisition of skills while promoting it. However, it is not always the case to say that seeking the awareness of players focusing on their languages is meaningless. Languages are the means of communication connecting one with another and their expression is one of the reliable confirmation methods although presenting various research challenges. In short, through languages, people can scientifically observe communications in a visible manner. Past researches made efforts to seek the cognition of participants practicing physical skills such as dart throwing\[16\], high jump, gymnastics, butterfly swimming\[17\], and three-ball cascade jug-

gling\[18\] from their verbal reports.

And the first author’s previous research outcomes also proved that cognitive transformation regarding start of sprint indicated the coordination between players’ actual feeling of speed and acceleration and the movements of their lower extremity by arm swing\[19\], [20]. Meanwhile, however, there have not been enough discussions yet on the cognition of change-of-direction movements such as “the movement to make a stop and then change the direction” which this study focuses on.

With this background, the purpose of this study is to, focusing on basketball as a ball game, reveal cognitive transformation in the process of acquiring skills for change-of-direction movements from the perspective of cognitive science. As the study method, we first extracted the cognitions of players practicing change-of-direction performance from their verbal reports and conducted a temporal analysis (refer to Fig. 1). As the significance of this study, if common factors and distinguishing patterns can be identified in the cognitive transformation of players during the process for acquiring skills, their cognition could also be an effective evaluation as well as a movement analysis from the perspective of biomechanics.

2. Method

2.1 Survey Period, Surveyed People and Instructor

The survey was conducted 40 times for 3 months from August 29 to November 28, 2020. Those surveyed were 8 university freshmen belonging to women’s basketball club of M University designated as a promising sports club. During the survey, 1 player withdrew from it due to reasons including her injury and accordingly 7 female basketball players were subject to analyses (their average age was 18.4 as of August 29, 2020).

Next, an instruction on skills for change-of-direction movements was provided by the second author (hereinafter “Instructor”). The second author’s instruction records are explained as follows. A skill acquisition process consisting
mainly of muscle strength trainings may harden the body of an exerciser because such trainings will place a load on the body and narrow its range of movement. For this reason, with the aim to departure from the instruction style emphasizing muscle strength trainings, Instructor produces physical movements centering on the body modification tailored to the characteristics of a relevant sport and relaxation, leading a high school girls basketball team to the national tournament for 7 times. In addition, he has won several national and international competitions.

2.2 Survey Procedure

2.2.1 Specific Practice Contents

The specific contents of the practice are as follows. In each of 40 practice sessions (about 120 to 150 minutes), the players practiced change-of-direction performance using the basketball court for about 10 to 15 minutes at the beginning of every practice (refer to Fig. 2 and Fig. 3). They shuttled back and forth on the basketball court from the level of walking to check the movement to the level of fast running change-of-direction performance in time.

During the practice, Instructor checked the players’ change-of-direction performance and provided instructions to each of them accordingly. In the practice hereunder, the players run thorough it while being aware of the 13 items as evaluation standards listed below (refer to Sect. 2.3.1 as described later). Additionally, in the practice using a basketball, they practiced several movements including those for changing a running direction while dribbling the ball in a one-on-one situation and when receiving the ball (refer to Fig. 4).

2.2.2 Methods for Collecting Verbal Reports by Players

The way to collect verbal reports to explore the changes in the players’ cognition is described as below. In the earliest possible stage after every practice of change-of-direction performance, their verbal reports were collected by instructing, using Google Forms, “Please freely enter how you have thought and felt after practicing the change-of-direction performance as well as your current impression of the way to move your body and the details of your physical feelings”.

2.2.3 Collecting Videos for Players’ Proficiency Evaluation

For Instructor to evaluate the proficiency level of survey subjects’ skills for changing a running direction, before (August 25) and after (December 1) the survey, two video cameras were used to record the players’ shuttling back and forth by change-of-direction on the vertically long basketball court (28m x 2 = 56m) from two directions: frontal and lateral directions (refer to Appendix A as described later). Recorded videos were saved in a PC in MOV format. The second author spent about 10 minutes per the player evaluating each
player while visually checking the videos on the PC screen randomly.

2.3 Procedures for Analyzing Instructor’s Evaluation

2.3.1 Instructor’s Standards for Evaluating Change-of-Direction Performance

In this study, Instructor provided skill instructions in line with 13 items as evaluation standards listed below.

(i) Position of Center of Gravity: To keep the center of gravity as high as possible and maintain the angle of knees wide by not bending them too much

(ii) Shift in Center of Gravity: To avoid the movements to kick the floor hard and raise thighs as much as possible and move naturally by shifting the center of gravity to the moving direction; To relax in starting particularly

(iii) Grounding Position of Feet: To move with turning the pelvis sideways; To make the grounding positions of feet a straight line

(iv) Landing: To land the foot right below the center of gravity in moving; To land with the entire sole at once

(v) Posture: Regarding the posture in moving, not to plunge the upper body forward by crouching the back too much

(vi) Pelvis: To move with maintaining the pelvis particular to the moving direction so that the pelvis will not open

(vii) Stride: To move with turning the body sideways and following the center of gravity; To enhance the flexibility of the hip joint in order to make a stride wide

(viii) Tension in Shoulder: To reduce the strong tension in the shoulder when swinging arms in starting and engaging in a change-of-direction movement

(ix) How to Swing Arms: To control the relaxation of shoulders and arms as forward as possible; Not to produce a movement to strongly pull the elbow backward

(x) Movement to Stop: Instead of stopping with the “one-two” rhythm, to stop the timing of “one” for smoothly shifting to the center of gravity to the next change of direction

(xi) Speed: To produce a fast, dynamic and energetic movement

(xii) Vision: To basically direct the vision to the opposite side of the moving direction and widely see a position higher than the eye level because basketball is a sport developing into all directions and therefore it is important to change the vision in engaging in a change-of-direction movement

(xiii) Restarts in Same Direction: To control the change in acceleration and speed when restarting in the same direction from smooth stops and slowdowns

2.3.2 Instructor’s Method for Analyzing Proficiency Level of Change-of-Direction Performance

It was reported that change-of-direction movements were associated with a variety of factors besides the ability to run in a straight line and no assessment method has been established yet [2], [8]. In this context, this study surveyed the acquisition degree of change-of-direction performance skills through an approach of evaluations given by Instructor who instructed the skills of change-of-direction movements.

Instructor visually examined a video in which the respective players practiced the change-of-direction movements before and after the survey and then quantitatively gave evaluations on a scale 1 to 10 (10 as the highest rating). As evaluation items, instructed contents such as (i) Position of Center of Gravity, (ii) Shift in Center of Gravity, (iii) Grounding Position of Feet, (iv) Landing, (v) Posture, (vi) Pelvis, (vii) Stride, (viii) Tension in Shoulder, (ix) How to Swing Arms, (x) Movement to Stop, (xi) Speed, (xii) Vision and (xiii) Restarts in Same Direction were set and the players were evaluated based on their total scores.

2.4 Procedures for Analyzing Players’ Self-Evaluation and Verbal Reports

2.4.1 Players’ Self-Evaluation of Proficiency Level

In laboratory experiments in which factors for novice players are controlled, it is often easy to collect quantitative data
Table 1  Procedure for analyzing verbal reports by SCAT

| Player | Text | <1> Noteworthy words or phrases from the text | <2> Paraphrases of <1> | <3> Concepts from the text that account for <2> | <4> Themes, constructs in considerations of context |
|--------|------|---------------------------------------------|------------------------|-----------------------------------------------|-------------------------------------------------|
| A      | I could move quickly by using the center of gravity | Use of center-of-gravity shift / Quick movement | Using center-of-gravity shifting / Experiencing quick movement | Center of gravity experience / Experience of speed | Center of Gravity Experience Factor / Speed and Acceleration Experience Factor |

Fig. 5  Level of proficiency focused on in this study

because their physical movements change greatly and large difference. Meanwhile, this study focuses on cases where the skills for changing running direction that had been already automated for experienced players were dialed back again to the level of cognitive learning and accordingly their physical skills are thought to be at a certain level even before the survey. Thus, it becomes necessary to make efforts for quantitatively collecting the data on the mastery level of the skills because of small difference (refer to Fig. 5).

Now, skills herein refer to the ability to resolve challenges which can be acquired through experiences and trainings [17], [21], [22]. In the field of sports, it is common for players to willingly understand instruction contents given by their coach and proactively make efforts for resolving challenges regarding their individual physical skills in view of the present in order to get closer to the ideal. Thus, with understanding differences between self-evaluations in the players’ practicing the skills for changing running direction and those before the practice as changes in their solving challenges, self-evaluations after the actual practice were compared with those before it with three answer choices such as “(−1) Getting Worse”, “(0) No Change” and “(+1) Getting Better” and then temporal changes in the degree of skill acquirement were evaluated by quantitatively cumulating self-evaluations by players. A positive cumulative total value obtained by this evaluation means that challenges regarding the skills for changing running direction have been resolved while a negative one means that they have not been resolved yet [23]. As for the timing of players’ self-evaluations, in the earliest possible stage after every practice, self-evaluations were collected by using Google Forms.

2.4.2 Methods for Analyzing Players’ Verbal Reports

Regarding the analysis of free descriptions in the verbal reports about skills, it becomes necessary to carefully examine all the data one by one. Meanwhile, the characteristics of a language such as ambiguity, similarity and polysemy frequently make it difficult to provide codes to the verbal reports.

This study performed coding using SCAT (Steps for Coding and Theorization) as a qualitative analysis method [24]. SCAT is a method to perform coding through the identification of appropriate concepts while first describing segmented data in a matrix and then reading out texts from bottom up. Because such an analysis process explicitly remains in the matrix, this method also has a function to reflect the validation of analyses and has been proved effective for relatively small-sized data. Specific procedures for coding the players’ verbal reports are shown in Table 1. In this study, an Excel form downloaded from SCAT website was used [25]. In SCAT, a story line is described by weaving the conceptual themes generated in <4> and recontextualization procedures are performed. Meanwhile, the main focus of this study is to seek cognitive transformations from multiple players’ verbal reports. Therefore, following a previous study that analyzed verbal reports by SCAT [18], the players’ verbal reports were classified into factors generated in <4>, and a plot graph was made using factors (refer to Table 3 and Table 4 as described later).

3. Result

3.1 Evaluation on Acquirement Degree of Change-of-Direction Movement

3.1.1 Evaluation by Instructor

Table 2 indicates evaluations quantitatively given by Instructor as to the players’ change-of-direction performance. Regarding the total scores for the 13 items, it was shown that the total scores of 6 players - A, B, C, D, F and G - after the
Table 2 Evaluation by Instructor

| Evaluation Items | (i) Position of Center of Gravity | (ii) Shift in Center of Gravity | (iii) Grounding Position of Feet | (iv) Landing | (v) Posture | (vi) Pelvis | (vii) Stride | (viii) Tension in Shoulder | (ix) How to Swing Arms | (x) Movement to Stop | (xi) Speed | (xii) Restarts in Same Direction | (xiii) Self-Evaluation | (xiv) Total Scores* |
|------------------|----------------------------------|------------------|------------------|---------|--------|--------|--------|----------------|----------------|----------------|-------|---------------------------|---------------|-----------------|
| A | Before | 5 | 6 | 4 | 5 | 4 | 4 | 6 | 5 | 5 | 6 | 6 | 6 | 5 | 67 |
|    | After  | 6 | 7 | 4 | 5 | 6 | 5 | 7 | 6 | 6 | 6 | 7 | 6 | 6 | 77 |
| B | Before | 4 | 4 | 6 | 5 | 4 | 6 | 6 | 5 | 6 | 5 | 5 | 6 | 5 | 68 |
|    | After  | 4 | 5 | 5 | 6 | 6 | 7 | 6 | 5 | 4 | 6 | 6 | 8 | 74 |
| C | Before | 3 | 6 | 5 | 6 | 3 | 5 | 6 | 5 | 6 | 7 | 6 | 4 | 6 | 68 |
|    | After  | 5 | 7 | 8 | 5 | 6 | 8 | 7 | 7 | 8 | 7 | 6 | 7 | 88 |
| D | Before | 6 | 6 | 6 | 3 | 3 | 6 | 4 | 5 | 4 | 5 | 3 | 4 | 6 | 61 |
|    | After  | 6 | 5 | 6 | 6 | 6 | 7 | 5 | 5 | 6 | 6 | 5 | 6 | 76 |
| E | Before | 6 | 6 | 5 | 5 | 6 | 4 | 6 | 6 | 5 | 4 | 6 | 4 | 69 |
|    | After  | 5 | 5 | 5 | 6 | 4 | 4 | 6 | 6 | 7 | 4 | 6 | 5 | 68 |
| F | Before | 5 | 5 | 5 | 5 | 6 | 6 | 6 | 5 | 5 | 5 | 6 | 6 | 4 | 69 |
|    | After  | 6 | 5 | 6 | 5 | 6 | 7 | 7 | 6 | 4 | 7 | 6 | 5 | 76 |
| G | Before | 6 | 4 | 5 | 4 | 6 | 3 | 3 | 5 | 5 | 4 | 4 | 6 | 5 | 60 |
|    | After  | 6 | 6 | 4 | 5 | 7 | 4 | 5 | 7 | 6 | 6 | 5 | 6 | 6 | 73 |

*p < .05: Items (i) to (xiii) were revalidated by Bonferroni correction

survey increased compared with those before it. Meanwhile, the total score of Player E was a negative value. The analysis of total scores before and after the survey using a (paired) t-test found a significant difference ($t(6) = 3.87, P = .004$). Another t-test conducted for the 13 evaluation items found notable differences in 6 items: (v) Posture ($t(6) = 3.27, P = .009$), (vii) Stride ($t(6) = 3.24, P = .009$), (viii) Tension in Shoulder ($t(6) = 3.24, P = .009$), (xi) Speed ($t(6) = 4.58, P = .002$), (xiii) Restarts in Same Direction ($t(6) = 3.36, P = .008$) and (xiv). On the other hand, repeating a t-test may result in Type I errors. Thus, a reverification test was conducted for the items from (i) through to (xiii) using Bonferroni correction, finding a significant difference in (xi) Speed (corrected, $t(6) = 4.58, P = .002$).

Since this study’s number of samples being 7 was small, the effect size of the total score (Hedges’ $g$) was calculated to examine the levels of skills acquired by the players from a different perspective than the t-test, obtaining the result of Hedges’ $g$ equaling to 2.13. These results revealed that the players as a whole had improved the speed of change-of-direction performance especially and acquired skills in the total.

3.1.2 Temporal Change in Cumulative Values of Self-Evaluations by Players

Figure 6 illustrates temporal changes in the cumulative values of self-evaluations by the player. The shifts in the scores present positive values regarding cumulative self-evaluations given by 6 players - A, B, C, D, F and G. In the meantime, the cumulative value of self-evaluation of Player E resulted in a negative value.

3.2 Cognitive Transformation of Players

3.2.1 Validity Results for Coding of Verbal Reports

In order to secure the validity of the coding of the verbal reports, the first author coded all verbal reports (243 cases) using SCAT and at the same time independently graded the verbal reports randomly extracted by the third author (122 cases/50.2% of the total) with reference to the method of a previous study in cognitive science [26]. Consequently, Cohen’s kappa coefficient was found to be 0.75 (concordance rate: 91.9%). Non-concordance ones were resolved through discussions and respective factors were defined. According to such definitions, the verbal reports were classified into the following 8 factors, “Goal Setting Factor”, “Lower Extremity Movement Factor”, “Change in Running Direction Factor”, “Speed and Acceleration Experience Factor”, “Center of Gravity Experience Factor”, “Relaxation Experience Factor”, “Vision Factors”, and “Practical Application Factor”. Those verbal reports not falling under any of these 8 factors (ex. “I don’t think I have paid much attention today.”) were
3.2.2 Reliability Results for Coding of Verbal Reports

Next, for the purpose of ensuring the reliability of the coding of the verbal reports, a graduate student specializing in cognitive science who did not know the purpose of this study was requested to, while understanding the factors’ definitions, read through a questionnaire listing all verbal reports (243 cases) and check-mark their appropriate box (requesting him to choose the prescribed number of answers from multiple choices). The comparison between the results of the first author and the third author and those of the graduate student found that Cohen’s kappa coefficient was 0.76 (concordance rate: 91.8%). The first author and the third author discussed again those not in concord with the graduate student’s answers and then finally decided the factors for the verbal reports.

classified into “Other Factors” (refer to Table 3 described the correspondence between each factors and Instructor’s evaluations).

### Table 3  Definitions of each factor and example of the verbal reports

| Factor                              | Definition                                                                 | Example of the verbal reports                                      | Correspondence with Instructor’s evaluations† |
|-------------------------------------|---------------------------------------------------------------------------|-------------------------------------------------------------------|----------------------------------------------|
| Goal Setting Factor                 | Contents Regarding Goal Setting                                           | I thought I would seek to be aware of my center of gravity to produce greater speed. | (i) to (xiii)                                |
| Lower Extremity Movement Factor     | Contents Regarding Movements of Lower Extremities such as Legs and Hip Joints | By being aware of the pelvis, I gained the deeper understanding of the relaxing feeling in my body. | (iii), (iv), (vi) and (vii)                  |
| Change in Running Direction Factor  | Contents regarding Change in Running Direction                           | I felt I was accelerating when changing the running direction.     | (x) and (xiii)                               |
| Speed and Acceleration Experience Factor | Contents regarding Actual Experience of Speed and Acceleration          | I felt I ran faster when changing the running direction with being aware of the pelvis. | (x), (xi) and (xiii)                         |
| Center of Gravity Experience Factor | Contents regarding Actual Experience of Shift in and Position of Center of Gravity | I realized I could move quickly by shifting my center of gravity. | (i) and (ii)                                 |
| Relaxation Experience Factor        | Contents regarding Actual Experience of Relaxation                       | I was able to move quickly with the sense of relaxation.          | (viii) and (ix)                              |
| Vision Factor                      | Contents regarding Direction of Eyes and Vision                          | I thought my vision got wider.                                    | (v) and (xii)                                |
| Practical Application Factor        | Contents regarding Actual Experience of Application to Practical Basketball | It became easier for me to defend my man.                        | (v), (x) and (xii)                           |
| Other Factors                      | Contents Other Than Above                                                | I don’t think I have paid much attention today.                   | Not applicable                               |

† Refer to 2.3.1 and Table 2 for an explanation about the numbering of the correspondence with Instructor’s evaluations.
| Goal Setting Factor | A | B | C | D | E | F | G |
|---------------------|---|---|---|---|---|---|---|
| 1                   | 1 |   |   |   |   |   |   |
| 2                   |   | 10|   |   |   |   |   |
| 3                   |   |   | 3 |   |   |   |   |
| 4                   |   |   |   | 1 |   |   |   |
| 5                   |   |   |   |   | 2 |   |   |
| 6                   |   |   |   |   |   | 2 |   |
| 7                   |   |   |   |   |   |   | 2 |

| Lower Extremity Movement Factor | A | B | C | D | E | F | G |
|---------------------------------|---|---|---|---|---|---|---|
| 1                               |   |   |   |   |   |   | 5 |
| 2                               |   |   |   |   |   |   | 6 |
| 3                               |   |   |   |   |   |   | 3 |
| 4                               |   |   |   |   |   |   | 17|
| 5                               |   |   |   |   |   | 14|   |
| 6                               |   |   |   |   |   | 2 |   |
| 7                               |   |   |   |   |   | 6 |   |

| Change in Running Direction Factor | A | B | C | D | E | F | G |
|------------------------------------|---|---|---|---|---|---|---|
| 1                                  |   |   |   |   |   |   | 12 |
| 2                                  |   |   |   |   |   |   | 21 |
| 3                                  |   |   |   |   |   |   | 15 |
| 4                                  |   |   |   |   |   | 9 |   |
| 5                                  |   |   |   |   |   | 13|   |
| 6                                  |   |   |   |   |   | 14|   |
| 7                                  |   |   |   |   |   | 15|   |

| Speed and Acceleration Experience Factor | A | B | C | D | E | F | G |
|-----------------------------------------|---|---|---|---|---|---|---|
| 1                                       |   |   |   |   |   |   | 12 |
| 2                                       |   |   |   |   |   |   | 13 |
| 3                                       |   |   |   |   |   |   | 3 |
| 4                                       |   |   |   |   |   |   | 15 |
| 5                                       |   |   |   |   |   | 21 |   |
| 6                                       |   |   |   |   |   | 4  |   |
| 7                                       |   |   |   |   |   | 3  |   |

| Center of Gravity Experience Factor | A | B | C | D | E | F | G |
|------------------------------------|---|---|---|---|---|---|---|
| 1                                  |   |   |   |   |   |   | 2 |
| 2                                  |   |   |   |   |   |   | 0 |
| 3                                  |   |   |   |   |   |   | 1 |
| 4                                  |   |   |   |   |   |   | 3 |
| 5                                  |   |   |   |   |   |   | 10|
| 6                                  |   |   |   |   |   | 1 |   |
| 7                                  |   |   |   |   |   | 0 |   |
3.2.3 Plot Graph for Cognitive Transformation

Based on the coding outcomes for the verbal reports, a plot graph showing the temporal changes in respective factors was made (refer to Appendix B as described later for the making procedure of the plot graph). Those not falling under any of defined factors were indicated with a blank space and those not having participated in the practice with a diagonal line. As for analyses, in addition to the generation trends of respective factors, the outliers for cases where the number of generated factors was extremely different from that for other players were quantitatively determined using the inter-quartile range.

As shown in the plot graph (refer to Table 4), for all of 7 players, “Goal Setting Factor” tended to be generated from the first half to the middle part of the survey period. It was confirmed that Player B’s verbal reports were generated in its second half as well, and the qualitative examination of verbal information found that those factors relating to relaxation and view were newly generated from the middle part to the second half. As for “Lower Extremity Movement Factor”, there was a tendency for the verbal reports of Player D and E to generate many of this factor. Regarding “Change in Running Direction Factor”, the verbal reports of all players tended to generate it. “Speed and Acceleration Experience Factor” tended to be generated from the verbal reports of all the players and, in particular, frequently from those of Player A, B, D and E. As far as “Center of Gravity Experience Factor” is concerned, there was a tendency for the verbal reports of Player E to generate it more frequently than those of other players and no generation was found through those of Player B and G. Regarding “Relaxation Experience Factor”, the verbal reports of Player A, B and E tended to frequently generate it while those of Player C and G did not generate any of it. As for “Vision Factor”, there was a tendency for the verbal reports of 6 players excluding Player E to generate it and those of Player B and G frequently generated it in particular. As far as “Practical Application Factor” tended to be generated from the verbal reports of Player A and E less frequently than by other players’, those of Player G generated many of it.

Here, the numbers generated by the players regarding each factor were quantitatively determined using the inter-
quartile range, finding that the outlier for Goal Setting Factor was Player B’s while that for Center of Gravity Experience Factor was Player E’s respectively.

4. Discussion

4.1 Cognitive Transformation for Change-of-Direction Movement

Based on the outcomes of this study, the factors were generated from verbal reports by Players that were made in accordance with the instruction contents given by Instructor, the timings and volumes of respective factors varied among the players. Meanwhile, analytical findings demonstrated a characteristic tendency regarding the following cognitive transformations.

In the beginning, it was shown that Goal Setting Factor was generated in the first part of all players’ verbal reports. In the sports field, there are many cases in which physical movements that players imagine differ from actual movements and accordingly they aim to acquire skills while correcting their movements as needed. While there is a need for the players to remember the movements and physical feelings of change-of-direction movements in newly learning them [27]. It is thought that they felt gaps between the movements in their mind and their actual ones and accordingly set their individual goals for acquiring skills.

Next, regarding Change in Running Direction Factor and Speed and Acceleration Experience Factor were confirmed to be generated from all the players’ verbal reports. In acquiring skills for change-of-direction movements, it is an important feeling to realize the top speed after changing a movement, the acceleration to distance oneself at a breath from the object after passing it [8]. In the evaluation about speed by Instructor, a significant difference was observed even after the revalidation using Bonferroni correction (refer to Table 2), which is considered to be common with the occurrence of cognitions regarding the speed and acceleration at the start of sprinting shown in previous study results [19].

4.2 Cognition about Lower Extremity Movement and Novelty of This Study

For all the players, the generation of Lower Extremity Movement Factor was observed regarding the movements of lower extremities such as legs and hip joints. Past studies confirmed cognitions of the bodily sensation of sprint speed and acceleration resulting from arm swings and coordination with leg (lower extremity) movements resulting from arm swings in sprinting [19]. It has been revealed that in arm swings not only does the spinal cord passively control coordinated movement patterns between upper and lower extremities but the cerebral cortex also actively controls them in order to adapt to the external environment changing by the minute [28]. In short, it is expected that for correcting automated movements like sprinting, it is less difficult to be aware of arm swings controlled actively rather than paying attention to the movement patterns of lower extremities controlled passively.

In the meantime, however, the outcomes of the change-of-direction performance focused on in this study did not find any factor for simple arm swings but instead only indicated cognitions concerning complicated lower extremity movements, which will be new knowledge never obtained before. Then, it is thought to be necessary to discuss whether or not in the actual practices the players, who were practicing arm swings and appropriately being coached by Instructor, were conscious only about their lower extremity movements considered to be more complexed instead of cognizing arm swings easier to be conscious about.

Past researches revealed that change-of-direction movement related to the change in a running speed and legs’ ground reaction force because it is the movement to change the barycentric velocity using a ground reaction force through the movements of legs [29], [30], and that in order to quickly shift the running direction it is necessary to kick the ground with one leg while keeping the balance with the other leg [31] from the biomechanical point of view.

Acquiring physical skills is an interaction between physical movements and cognitions [32], [33] and therefore it is important to match the evaluations of both factors as far as possible. It could be considered that in practicing change-of-direction performance, the players have difficulty being conscious about several movements and not being aware of the movements of their legs and arms concurrently. That the outcomes of this study did not find any cognition of arm swings and find cognition of lower extremity movements is thought to support the past study’s assertion that skills are acquired through an interaction between movements and cognitions.

4.3 Differences in Cognitive Transformation in Terms of Skill Acquisition Level

For the 6 players except Player E, Instructor’s evaluations in Table 2 showed a significant difference in the overall scores before and after the survey, and, furthermore, the cumulative values of the players’ temporal self-evaluations shown in Fig. 6 were positive ones steadily, suggesting that the players acquired the skills for change-of-direction performance.

On the other hand, Player E’s self-evaluation was a negative value (~2 points) and Instructor’s total evaluation on this player was a negative one as well, drawing a reasonable conclusion that Player E failed to acquire the skills for change-of-direction movements. The outliers for Center of Gravity Experience Factor were quantitatively determined using the inter-quartile range, finding that Player E generated it much more frequently than other players. Hamill et al. (1987) pointed out that centrifugal force works on runners’ center of gravity when they are doing the change-of-direction performance [34], on the other hand trying to voluntarily control the details of exercises by paying too much attention to the inside of the body would deteriorate exercise performances due to the collapse of total body coordi-
nation [28]. It is considered that Player E failed to acquire the skills for change-of-direction movements since she had paid much attention to the position of and shift in the center of gravity which is thought to be quite challenging.

Meanwhile, as the characteristic tendencies of Player E, the generation of Vision Factor was not confirmed and that of Practical Application Factor was observed less frequently than other players. Vision Factor and Practical Application Factor can be understood as the cognition of a space being outside players instead of the ones inside their body such as the movements of body parts, the center of gravity and relaxation. Ichikawa et al. (2015) reported that the participants who did not develop trained while focusing on their specific physical movements [18]. Suwa (2008) suggested that one’s performance improves when his/her attention shifts from individual body parts to the whole body in the process of acquiring physical skills [16]. In explaining “the phenomenal structure of tacit knowing”, Polanyi (2009) stated, “…we are aware of the proximal term of an act of tacit knowing in the appearance of its distal term; …[35]”. If translating this explanation to skill acquisition, the realization of individual exercises as proximal terms could be achieved by shifting the cognition to distal terms.

This is also supported by the findings that Center of Gravity Experience Factor were few for the remaining players who were found to have acquired physical skills and further that their generation of View Factor and Practical Application Factor were recognized frequently. In the meantime, it was suggested that Player E might not adjust well the acquisition of skills for change-of-direction movements by paying attention to the center of gravity inside her body as proximal terms instead of distal terms. These considerations provided the design guidelines of coaching through verbal communication, such as the possibility of understanding skill proficiency levels from the players’ verbal reports regarding the center of gravity.

5. Conclusion

The purpose of this study was to reveal cognitive transformation in the skill acquisition process for change-of-direction movements. Consequently, as cognitive transformation in the skill acquisition process for change-of-direction movements, four items such as (1) goal setting for skill acquisition, (2) experience of change in Running Direction, (3) experience of speed and acceleration and (4) experience of the movement of lower extremities such as legs and hip joints were suggested as common cognitive transformation. In addition, cognitive transformation varied by the degree of skill acquisition for change-of-direction movements, it was indicated that paying too much attention to body feelings including the position of and shift in the center of gravity in the body posed an obstacle to the skill acquisition for change-of-direction movements. While the cognition of sprinting is originally what associated with the high level of individuality being developed as the subjective view of ball sports players, the results of this study identified the characteristics of cognition through common cognitive transformation and the degree of skill acquisition and accordingly a design policy was obtained regarding skill instructions for change-of-direction movements using words of the players as indexes such as being able to understand the players’ level of proficiency based on the contents of the verbal reports (for example, content about the center of gravity).

As a future challenge, because this study analyzed the data of 7 players, for the purpose of substantiating the knowledge obtained, it is thought to be essential to accumulate research data on additional players and ball games. While the main purpose of this study was to elucidate the players’ temporal cognitive changes in the process of acquiring skills from their verbal reports, it is also important to discuss them from the perspective of verbal communication between the two parties such as how the instructor’s verbal communication affects players’ cognitions. Therefore, as a future task, we are considering collecting data on the instructor’s words for players.

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Appendix A: Collecting Videos of Surveyed Players’ Proficiency Evaluation

Two cameras were used to capture the players’ shuttling back and forth on the vertically long basketball court, once from the frontal direction and once from the lateral direction against the direction of travel. Figure A-1 shows a scene captured from the frontal direction.

Appendix B: Analysis Procedure of Players’ Verbal Reports

Figure A-2 intends to briefly explain procedures to make a plot graph by coding the players’ verbal reports. In a case where analytical findings did not match at the stage of the coding of the verbal reports, the authors resolved it through discussions.
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