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Relationship Between Bird's-Eye View Cognition and Visual Search Behavior

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ABSTRACT

Acquisition of visual search behaviors specific to the bird's-eye view can improve its ability, which in turn will improve the ability to judge a situation accurately. This study aimed to develop a better training program to improve the bird's-eye view ability. Experiment to investigate the effects of training on bird's-eye view ability, which was developed based on previous research, showed that training increased scores on three-choice questions, and was particularly effective if the rearrangement of placements was allowed for the trainer. Additionally, a questionnaire survey revealed that the cognitive method changed to awareness of relative positional relationships through the experiment. These findings suggest that training may improve the ability to look down and influence visual search behaviors. Moreover, experimental results investigating the influence of the improvement in cognitive ability because of the bird's-eye view on visual search behavior suggested that the bird's-eye view ability may have been improved by increasing the number of pivot movements through training.

Keywords: Bird's-eye view, Cognition, Visual search behavior, Virtual reality

INTRODUCTION

Generally, professional soccer players excel in situational judgment and express their game situation as if viewing the game from directly above the pitch. This cognitive method is called the bird's-eye view, and is considered important for accurate situational judgment. Moreover, expert soccer players have specific visual search behaviors for various situations (Natsuhara et al. 2017). For example, in a pass decision-making task in a complex game situation, expert players position their gaze on the defender before receiving the pass, and shift their gaze from the defender to a teammate before executing the pass (Natsuhara et al. 2015). In 11-on-11 defensive situations, unskilled players tend to focus more on the ball and the player passing the ball, whereas expert players tend to focus on the movement, position, and space of players but now the ball (Roca et al. 2011). Thus, although the gaze position differs, expert soccer players have specific visual search behaviors for various situations, which are considered to be goal-directed information-gathering strategies. This suggests that there may also be specific visual search behaviors when judging a situation based on cognition from the bird's-eye view. We believe that the acquisition of visual search behaviors specific to the bird's-eye view improves its ability, which, in turn, improves the ability to judge the situation accurately.

Therefore, in this study, we investigated the influence of the improvements in bird's-eye view ability on visual search behavior by training with Virtual Reality, which has been developed in a previous study (Shitamori et al. 2016). As the visual search behavior specific to a bird's-eye view becomes clearer, it is expected that better training will be developed by adding functions to assist or guide visual search behavior.

OVERVIEW OF BIRD'S-EYE VIEW ABILITY TRAINING SYSTEM

A virtual space was constructed using the Unity game engine, and VR images were presented using a head-mounted display (HMD). An HTC VIVE controller was used as the input device.

The system consisted of a training task to train the bird's-eye view ability, and a three-choice question to evaluate it.

Training Tasks

In the training task, ten player objects (five red and, five blue) were placed on a soccer court. The trainee watches a first-person video showing a 360° view from the center of the pitch as shown in Figure 1, for 10 seconds, and then arranges the player objects in a bird's-eye view, as shown in Figure 2.

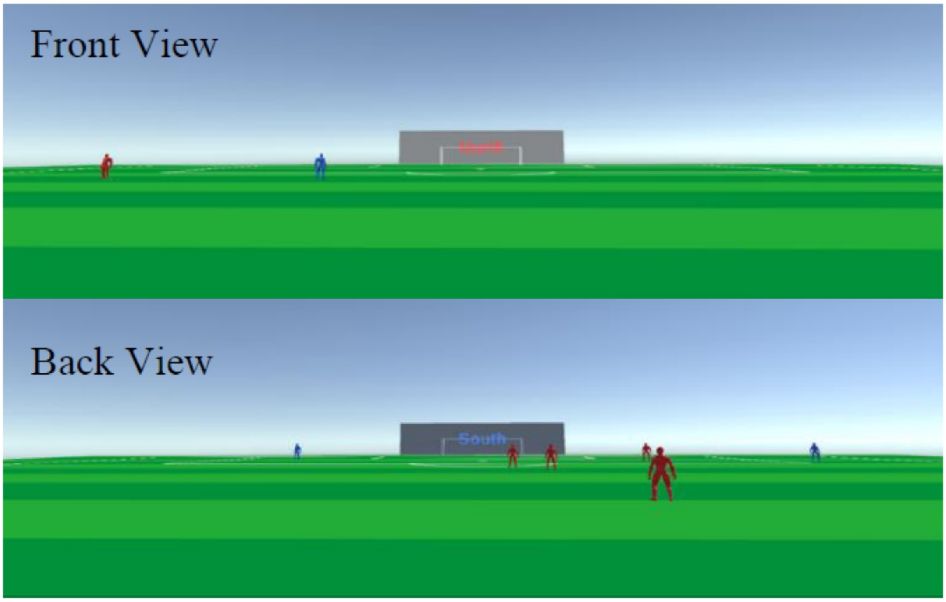

Figure 1: View of the first-person video.

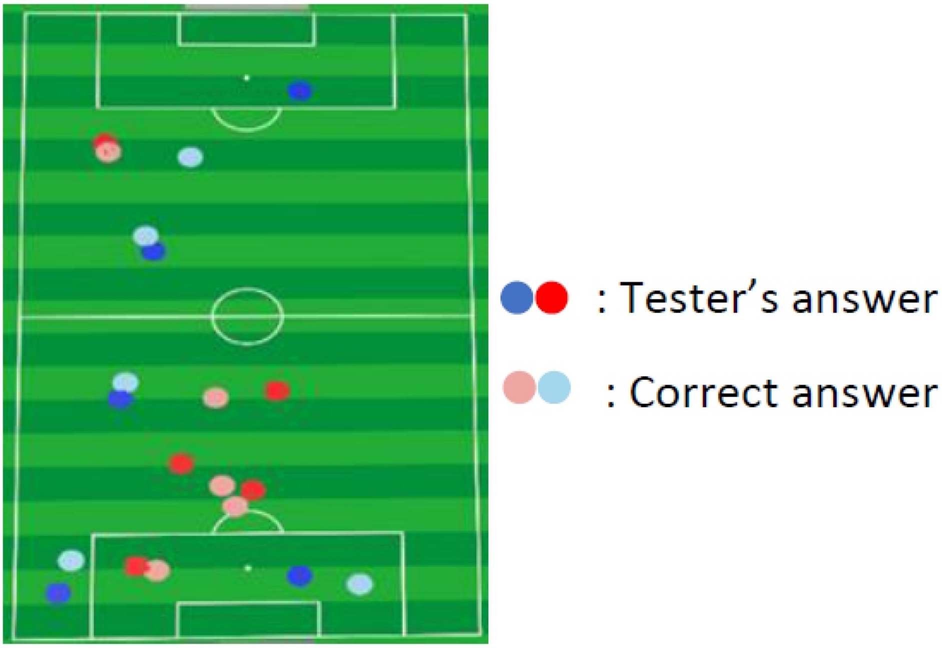

Figure 2: Bird's-eye view map.

The trainee then checks the placement of the objects and the correct placement and repeats this process until the trainee declares that the image of the placement of the objects from the bird's-eye viewpoint matches the actual placement of the objects.

Three-Choice Question

For the three-choice question, the trainee first viewed the first-person video for 10 seconds, as in the training task. Next, three bird's-eye views of the player objects are shown at one-second intervals, and the trainees are asked to choose the one they think is the same as the arrangement they saw in the first-person video and to indicate their confidence level in their choice. The three bird's-eye views shown for each choice consisted of one correct placement and two randomly shifted by 0–5 m in the vertical and horizontal directions from the correct placement of each object.

ASSESSING THE IMPACT OF BIRD'S-EYE VIEW ABILITY TRAINING

First, a bird's-eye view training system was developed based on a previous study (Shitamori et al. 2016), and the effect of the training on bird's-eye view ability was evaluated.

Experiment

In the experiment, VR images were presented using an HTC VIVE Pro Eye HMD. Nine Japanese male participants (22.3±1.1 years old) were divided into three groups: experimental group, control group 1, and control group 2.

In the experimental group, the trainee performed the entire training task. In control group 1, the training task consisted of viewing a first-person viewpoint image and correct placement of the answers, whereas in control group 2, the training task consisted of viewing a first-person viewpoint image only. The participants first answered 10 three-choice questions as a pre-task, then performed the training task ten times, and finally answered 10 post-task three-choice questions. The pre- and post-task questions were different. At the end of the experiment, the participants were asked to respond to a questionnaire to indicate any changes in their cognitive abilities that they felt through the experiment. This study was conducted with the approval of the Ethics Committee on Research Involving Human Subjects at Saitama University (R4-E-23).

Results

The number of correct answers to the 10 three-choice questions in the pre- and post-task periods were calculated on a 10-point scale. Table 1 shows the mean score difference and score ratio of the pre- and post-tasks for the experimental group, control group 1, and control group 2.

In the questionnaire, all six participants in experimental and control group 1 responded that they had become more aware of their relative positions during the experiment. Only the top three scorers (one from the experimental group and two from control group 1) responded that they became graphically aware of positional relationships. Additionally, only two participants in the experimental group stopped shaking their heads as much as they were expected to.

Discussion

Table 1 shows that the mean score difference was negative only in control group 2, with the mean score ratio being less than 1, suggesting that the training task in control group 2, with only the first-person viewing of the video, had no effect on increasing the scores, and that correct placement during the training task in the experimental and control group 1 was the factor that increased the scores. The mean score ratios were higher in the control group than in the experimental group. Furthermore, the mean score ratio of the experimental group was higher than that of control group 1, suggesting that the experimental group had a greater increase in scores than control group 1 and that the training was more effective when both reordering and correct placement were performed than when only correct placement was performed.

Table 1. Comparison of mean score difference and mean score ratio by group.

Group name	Score difference[−]	Score ratio[−]
Experimental	2.33	1.72
Control1	2.33	1.53
Control2	−0.333	0.952

Moreover, participants with increased scores indicated that they perceived the positional relationship relatively (especially graphically), suggesting that they may have acquired a bird's-eye view of cognition through the training conducted in this experiment. Furthermore, only two participants in the experimental group answered that they stopped shaking their heads frequently, suggesting that the training may have influenced their visual search behavior.

RELATIONSHIP BETWEEN BIRD'S-EYE VIEW COGNITION AND VISUAL SEARCH BEHAVIOR

An experiment to evaluate the effects of bird's-eye view training on its ability suggested that the training may have helped trainees acquire a bird's-eye view cognitive method and influenced their visual search behavior. To evaluate the relationship between improvements in cognitive ability and visual search behavior, we conducted an experiment using a bird's-eye view training system.

Experiment

We used HTC's VIVE Pro Eye HMD with a Tobii eye tracker to present VR images and measure eye and head movements. Ten Japanese males (22.7±0.74 years old) participated in the experiment. The participants first answered 10 three-choice questions as a pre-task, then performed the training task ten times, and finally answered 10 post-task three-choice questions. The pre- and post-task questions were kept different. At the end of the experiment, the participants responded to a questionnaire to indicate the changes in their cognitive abilities that they felt through the experiment. This study was conducted with the approval of the Ethics Committee on Research Involving Human Subjects at Saitama University (R4-E-23).

Eye Movement

Here, the gazing state was defined as a state in which the eye movement speed was 10 °/s or less for 133 ms (eight frames) or longer, in accordance with a previous study (Kato and Fukuda 2002). Based on this definition, the number of gazes and the total gazing time were calculated from the gaze data while viewing the first-person video and answering the three-choice questions.

Head Movement

To evaluate the effect of bird's-eye view training on its ability, we defined the number of pivoting movements and analyzed them because the training also affected pivoting movements.

The rotational motion of the HMD around the y-axis (in the left-right pivoting direction) was calculated as the number of pivoting movements. In a preliminary experiment, the maximum angular velocity was 19 °/s when the subject stood still while looking forward in a natural posture. Based on this definition, we calculated the number of pivots made by the participant from HMD tracking data while viewing the first-person video and answering a three-choice question.

Results

The box-and-whisker plots in Figure 3 show the number of pivots for correct and incorrect answers, and the Mann-Whitney U test for the number of pivots for correct and incorrect answers showed significant differences at the 5% significance level. As shown in Figure 4, the number of correct answers in the pre- and post-assignments was calculated as a score of 10, and the correlation between the score for the three-choice questions and the average number of pivots in the pre- and post-assignment was calculated. A weak positive correlation coefficient ($r = 0.37$) was found. Figure 5 shows that the correlation coefficient between the scores and average number of pivots was weakly positive. As shown in Figure 5, the difference between the pre- and post-assignment scores and the average number of pivots increased for the nine participants whose scores increased from pre- to post-assignment, and it decreased for the one participant whose scores decreased.

There was no significant difference between the results of correct and incorrect answers in terms of the number of gazes and gazing time, nor was there any significant trend between the mean and scores.

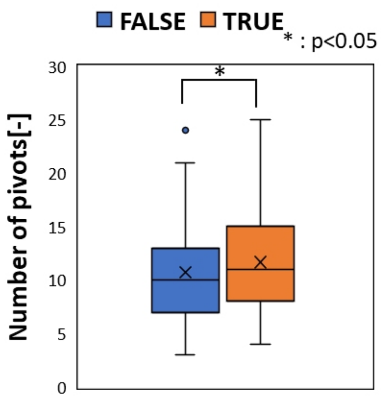

Figure 3: The number of pivots for correct and incorrect answers.

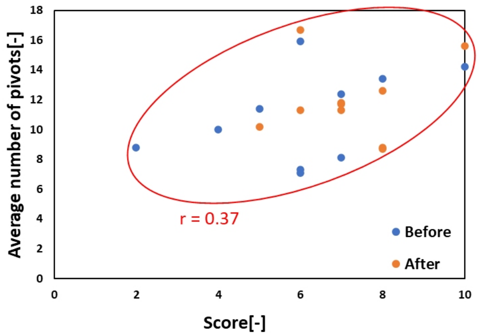

Figure 4: Correlation between scores and average number of pivots.

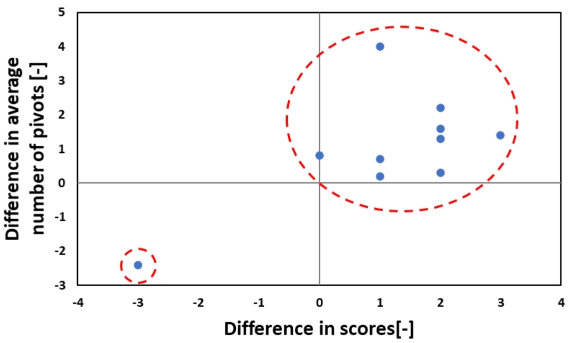

Figure 5: Correlation between the differences in scores and average number of pivots.

DISCUSSION

There was a significant difference in the number of pivots between correct and incorrect answers to the three-choice questions, and a weak positive correlation between the score and the average number of pivots, indicating that an increase in the number of pivots increases the score. The number of pivots increased after training, suggesting that the training may have increased the number of pivots. Besides, the number of times a player swivels his head during a soccer game is positively correlated with the number of successful passes (Marius et al. 2022). Accurate situational judgment is necessary for successful passing, and it is believed that cognition from a bird's-eye view is important for accurate situational judgment. Therefore, increasing the number of pivoting movements may improve the bird's-eye view, which in turn may improve the ability to judge the situation accurately.

No significant differences or trends were found in the number of gazing instances or gazing duration. In a previous study (Natsuhara et al. 2013) conducted on skilled and unskilled soccer players, there was no difference in the number and duration of gazing between them but the number of gazing targets was greater for skilled players than for unskilled players. Because the number of pivoting movements might increase when the number of gazing targets increases, it should be considered as a parameter in future studies.

Expert sports players use three superior techniques to perceive and recognize in sports situations: visual search strategy, pattern recognition, and prediction (Williams et al. 2002). To examine the mechanism of bird's-eye view, this study focused specifically on visual search strategies among the three. For this purpose, we developed a bird's-eye view training system in which all memorized arrangements were randomly arranged and did not include soccer scenarios related to pattern recognition and prediction. The results revealed a tendency for the number of pivots to be higher for those who performed better on the three-choice questions in this training system. Although this study did not fully explain the visual search strategy related to the bird's-eye view based on the number of pivots, number of gazes, and gazing time, it was found that the high frequency of pivoting, which is a characteristic of expert soccer players, may be related to the bird's-eye view. Therefore, although it cannot be said that all expert soccer players have a bird's-eye view, it is possible that many possess its cognitive ability. We believe that further clarification on the mechanism of bird's-eye view may be achieved by investigating the relationship between bird's-eye view, pattern recognition, and prediction abilities possessed by skilled sportspeople.

CONCLUSION

In this study, we conducted experiments to investigate the influence of improvement in cognitive ability of bird's-eye view on visual search behavior. The results suggest that the number of pivoting movements increased by the training may have improved the bird's-eye-view ability. In future, we will further investigate the effects of visual search behavior by adding indicators such as the number of objects to be gazed at. Using these findings, we will add a function to assist and guide visual search behavior, as well as investigate the relationship between pattern recognition and prediction and bird's-eye view to further clarify the mechanism of bird's-eye view and improve training.

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