Relationship between Initiation of Gaze Stabilisation and Angle of Head and Trunk Movement during a Jump with Full Turn

Yusuke Sato[1], Shuko Torii[2] and Masaharu Sasaki[3]
[1]College of Commerce, Nihon University, Tokyo, Japan
[2]College of Arts and Sciences, University of Tokyo, Tokyo, Japan
[3]Faculty of Liberal Arts, Hirosaki Gakuin University, Aomori, Japan

Keywords: Eye Movement, Gaze Behaviour, Gymnastics, Landing, Spatial Orientation.

Abstract: Over time it has become clear that there is a relationship between visual spotting and movement in the air in gymnasts, but that relationship during basic skills that are simple for skilled gymnasts, such as a jump with full turn, is still unclear. The aim of this study was to reveal the relationship between the initiation of gaze stabilisation and the magnitude of body rotation angle during landing. The participants were 10 skilled male gymnasts. Their eye movements during jumps were measured using electrooculography and their body movements were recorded using two high-speed digital cameras. The initiation of gaze stabilisation immediately before landing was determined by combining eye and head movement data. We found various relationships between initiation of gaze stabilisation and jump movement in gymnasts, such as a positive correlation between the gaze stabilisation and the head-on-trunk angle at the initiation of gaze stabilisation and angles of trunk rotation at the landing. The results suggest that gymnasts who can look at locations quicker before landing might have an advantage in completing rotation, as well as gaining enough time to use visual information. For achieving early gaze stabilisation, it may be necessary to rotate the head ahead of the trunk.

1 INTRODUCTION

Gymnasts perform in a fixed environment in which they use visual, vestibular, and somatosensory information to execute their routine (Sands, 1991). In particular, visual information is important for gymnasts to control their landings with precision (Lee et al., 1992), even when performing basic elements, such as a jump with full turn (Figure 1) (Rezette and Amblard, 1985).

The jump with full turn requires a rotation of 360 deg about the longitudinal body axis during a straight jump. Gymnasts stabilise their gaze immediately before landing (Sato et al., 2015). Gaze stabilization, so-called "spotting" (Davlin et al., 2004; Laws et al., 2002) during landing is especially important for control of landing (Berthoz and Pozzo, 1994) and the magnitude of rotation (Heinen et al., 2012a).

Interestingly, there is a possibility that spotting not only enables movement control using visual information obtained through gaze stabilisation, but also directly affects a performer's movement (Heinen et al., 2012; Heinen and Vollmer, 2014). For example, manipulating the fixation point during the takeoff phase in a back tuck somersault influences the duration of the flight phase (Heinen and Vollmer, 2014). Heinen et al., (2012b) also reported that there is a relationship between visual spotting and movement when performing high bar dismounts; for example, fixations during the preparatory giant swings are correlated with flight distance during dismount. There is an interplay of eye-head movements with gaze displacement and body movements even while executing whole-body rotation without a jump

Figure 1: Jump with full turn (360°).

(Hollands et al., 2004). Therefore, it was hypothesised that gaze stabilisation immediately before landing during a jump with full turn correlates the body movements. The aim of this study was to reveal the relationship between the initiation of gaze

Sato, Y., Torii, S. and Sasaki, M..
Relationship between Initiation of Gaze Stabilisation and Angle of Head and Trunk Movement during a Jump with Full Turn.
In *Proceedings of the 3rd International Congress on Sport Sciences Research and Technology Support (icSPORTS 2015)*, pages 165-168
ISBN: 978-989-758-159-5

stabilisation and the magnitude of body rotation angle during landing.

Clarifying this problem may contribute to developing a more effective training programme. When gymnasts perform aerial movements with longitudinal axes, a lack of rotation at landing leads to deductions of score in competitive gymnastics (Fédération Internationale de Gymnastique, 2013). If gymnasts can quickly stabilise their gazes, it has a positive effect on controlling the magnitude of rotation, an advantage of early gaze stabilisation that may be suggested in addition to those of previous studies.

2 METHODS

2.1 Participants

The participants were 10 skilled male gymnasts. After receiving a written explanation of the aim and content of the experiment, all participants provided written informed consent.

2.2 Apparatus and Procedure

The participants performed a jump with full turn in a gymnasium. A soft mat was put on a floor to ensure safety. Participants wore comfortable clothes such as sportswear and were barefoot for all tasks. Before the experimental trial, markers were attached to the auricles and acromia of each participant in order to easily determine head and trunk movements in space.

The experimental task was a jump with full turn. Participants jumped vertically and rotated 360 deg about the longitudinal body axis. They stood upright in the centre of the safety mat and then jumped and were free to select the direction of rotation. We instructed the participants to look forward at the beginning of each trial, and to make a perfect landing. They were allowed to practice freely before the experiment and then were prepared for the experiment. Each participant performed a jump with full turn three times. The experimenter monitored eye movement data during the jump, and if the data were noisy, the gymnasts performed the jump again. Landing performance was estimated in conformity to the international competition rules for men's artistic gymnastics (Fédération Internationale de Gymnastique, 2013).

In order to estimate gaze, horizontal eye movement and head movement were measured. Eye movement during the jump was clarified by electrooculography (EOG) using a wireless system (500 Hz; BioLog DL-4000; S&ME, Tokyo, Japan). An electrode was attached to the outer canthus of each eye. Simultaneously, to determine horizontal head and trunk movement, the experimental trials were recorded using two high-speed digital cameras (240f/s, EX-F, Casio, Tokyo, Japan). The cameras were placed at positions diagonally in front of the mat.

2.3 Data Acquisition and Analysis

The angle of eye movement was calculated by calibrating EOG. The recorded movement data were downloaded to a computer, and measurement points were digitised using motion analysis software (Frame-DIASIV, DKH Inc., Tokyo, Japan). The three-dimensional coordinates of the head and trunk points were obtained by direct linear transformation (DLT). The angle of horizontal head movement was obtained from the line connecting the auricles. The angle of horizontal trunk movement was obtained using the line connecting the acromia. The head and trunk data were filtered using a Butterworth low-pass filter with a 6-Hz cutoff.

The optical signal was recorded by the cameras, adding in the PC to synchronise the kinematics and eye movement data. To synchronise, we use the body movement data as a basis and picked eye movement data to synchronise with head data.

Gaze during the jumps was determined by combining eye and head movement data (Anastasopoulos et al., 2009). Head-on-trunk movement was obtained from the angle between the head and trunk segments. The initiation time of gaze stabilisation before landing was defined as the point in time of the completion of gaze shifting in the rotational direction, and was calculated on the basis of landing. Landing was defined as the time when the participant's foot visibly made contact with the ground.

Variables pertaining to the performance of each participant were used for statistical analysis. This analysis was performed using SPSS 18.0 for Windows (IBM, Tokyo, Japan). The Pearson correlation coefficients between head/trunk/head-on-trunk angles at the time of initiation of gaze stabilisation and head/trunk angles at the landing and initiation time of gaze stabilisation were used to evaluate the relationship between gaze behaviour and movement kinematics in gymnasts. The level of significance was set at $p < .05$.

3 RESULTS

All gymnasts performed perfect landings. Their eyes rotated in the direction opposite to that of their head movement before landing. Almost at the same time, their gazes started to stabilise. The angles of head and trunk movement were almost 0 deg at the beginning of the trial, and after the rotation, the angles had reached approximately 360 deg.

The mean angle of head movement at the initiation of gaze stabilisation was 299.71 ± 8.47 deg; the mean angle of trunk movement at the initiation of gaze stabilisation was 263.64 ± 22.57 deg; the mean angle of head-on-trunk at the initiation of gaze stabilisation was 35.40 ± 19.19 deg; the mean angle of head movement at the landing was 316.15 ± 17.12 deg, and the mean angle of trunk movement at the landing was 306.07 ± 18.05 deg. Therefore, head movement preceded trunk movement at the initiation of gaze stabilisation.

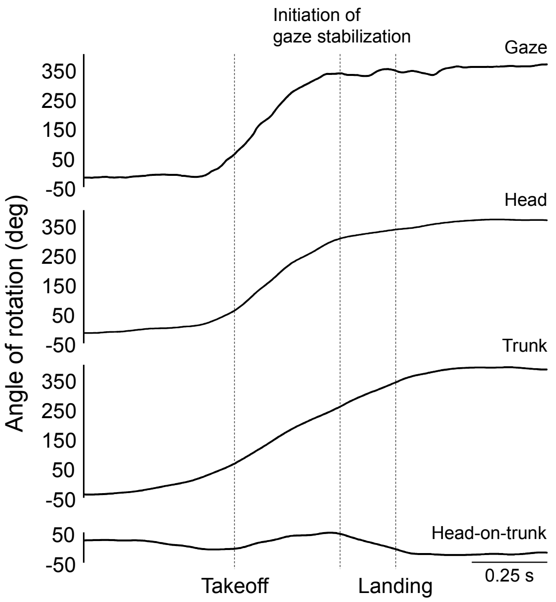

Figure 2: Example of gaze and head/trunk/head-on-trunk movements during a jump with full turn.

The analysis revealed certain relationships between the initiation of gaze stabilisation and the jump movement in gymnasts. Table 1 shows the correlation coefficients. According to these results, the initiation time of gaze stabilisation is negatively correlated with the head/trunk angle at the initiation of gaze stabilisation and positively correlated with the head-on-trunk angle at the initiation of gaze stabilisation, head angle and trunk angle at landing. Therefore, when gymnasts execute quick gaze stabilisation before landing, the angle of head and trunk movement is smaller at that time and larger at landing.

4 DISCUSSION

The aim of this study was to reveal the relationship between initiation of gaze stabilisation and movement kinematics before landing. Although gymnasts use visual information to land completely during a jump with turn (Rezette and Amblard, 1985) through gaze stabilisation (Sato et al., 2014), the relationship between gaze stabilisation before landing and magnitude of rotation was unclear. Clarifying this problem may contribute to developing a more effective training program.

The gymnasts' initiation of gaze stabilisation correlated with all the kinematic variables in this study. A functional relationship between gaze behaviour and movement has been reported in recent years (Heinen et al., 2012b; von Lassberg et al., 2014). This study's results also showed that gaze behaviour is linked to magnitude of body rotation angle. The gaze stabilisation that occurs before landing is thought to lead to optimal landing and precise rotation (Heinen et al., 2012a; Hondzinski and Darling, 2001). Early gaze stabilisation before landing probably provides a time margin in which to use the visual information and control landing. Accordingly, to reveal how gymnasts look at locations quickly would be an interesting research project. From this point of view, it would be important to note that there is a relationship between initiation time of gaze stabilisation and head-on-trunk angle. For achieving early gaze stabilisation, it may be necessary to rotate the head ahead of the trunk. Interestingly, the gymnasts who started to stabilise their gazes earliest before landing rotated their bodies more. A lack of rotation leads to deductions in gymnastics (Fédération Internationale de Gymnastique, 2013). Therefore gymnasts who can look at locations quicker before landing might have an advantage in completing rotation, as well as gaining enough time to use visual information.

Table 1: Correlation coefficients between gaze parameters and rotational angle in gymnasts.

Variable	Initiation of gaze stabilization			Landing	
	Head	Trunk	Head-on-trunk	Head	Trunk
Gaze stabilisation	-.73*	-.92**	.77**	.75*	.81**

Note. Gaze stabilisation = Initiation of gaze stabilisation
**: $p < .01$. *: $p < .05$.

We found that initiation time of gaze stabilisation correlates with magnitude of rotation. However, the present study cannot identify a way for gymnasts to look more quickly at locations before landing, the main factor of the quick look. From this viewpoint, it would be very useful for a future study to explore how gymnasts quickly start to stabilise their gaze before landing.

There is a relationship between gaze behaviour and body movements during the jump with full turn, but the relationship between eye-body interactions and expertise is unclear. Future studies are necessary to determine the influence of expertise on eye-body interactions by comparing between experts and novices (Heinen, 2011).

5 CONCLUSIONS

The aim of this study was to reveal the relationship between initiation of gaze stabilisation and movement kinematics before landing. We found various relationships between initiation of gaze stabilisation and the jump movement in gymnasts; for example, positive correlation between gaze stabilisation and angle of trunk rotation at landing. The results suggest that gymnasts who can look at locations quicker before landing might have an advantage in completing rotation, as well as using visual information to control landing. For achieving early gaze stabilisation, it may be necessary to rotate the head ahead of the trunk. It is hoped that the findings obtained by the present study will contribute to the development of new training materials and methods.

ACKNOWLEDGEMENTS

This research was supported by JSPS KAKENHI Grant-in-Aid for Young Scientists (B), Grant Number 26750280.

REFERENCES

Anastasopoulos, D., Ziavra, N., Hollands, M., & Bronstein, A. (2009). Gaze displacement and inter-segmental coordination during large whole body voluntary rotations. *Experimental Brain Research*, 193(3), 323-336.

Berthoz, A., & Pozzo, T. (1994). Head and body coordination during locomotion and complex movements. In S.P. Swinnen, J. Massion, & H. Herer (Eds.), *Interlimb coordination: Neural, dynamical, and cognitive constraints* (pp. 147-165). San Diego: Academic Press.

Davlin, C. D., Sands, W. A., & Shultz, B. B. (2004). Do gymnasts" spot" during a back tuck somersault. *International Sports Journal*, 8(2), 72-79.

Fédération Internationale de Gymnastique. (2013). *2013-2016 Code of Points: Men's Artistic Gymnastics*. Retrieved from http://www.fig-gymnastics.com/site/rules/disciplines/art.

Heinen, T., Velentzas, K., & Vinken, P. M. (2012a). Analyzing gaze behavior in complex (aerial) skills. *International Journal of Sport Science and Engineering*, 6(3), 165-174.

Heinen, T., Velentzas, K., & Vinken, P. M. (2012b). Functional relationships between gaze behavior and movement kinematics when performing high bar dismounts–an exploratory study. *Human Movement*, 13(3), 218-224.

Hollands, M. A., Ziavra, N. V., & Bronstein, A. M. (2004). A new paradigm to investigate the roles of head and eye movements in the coordination of whole-body movements. *Experimental brain research*, 154(2), 261-266.

Hondzinski, J. M., & Darling, W. G. (2001). Aerial somersault performance under three visual conditions. *Motor Control*, 5(3), 281-300.

Laws, K., Sugano, A., & Swope, M. (2002). Pirouettes. *Physics and the art of dance: Understanding movement* (pp. 63-85). New York: Oxford University Press.

Lee, D. N., Young, D. S., & Rewt, D. (1992). How do somersaulters land on their feet? *Journal of Experimental Psychology: Human Perception and Performance*, 18(4), 1195 -1202.

Rezette, D., & Amblard, B. (1985). Orientation versus motion visual cues to control sensorimotor skills in some acrobatic leaps. *Human Movement Science*, 4(4), 297-306.

Sato, Y., Torii, S., Sasaki, M., & Heinen T. (2015). *Gaze Shift Patterns during a Jump with Full Turn in Gymnasts*. Manuscript in preparation.

Sands, W. A. (1991). Spatial orientation while somersaulting. *Technique*, 11(1), 16-19.

von Lassberg, C., Beykirch, K. A., Mohler, B. J., & Bülthoff, H. H. (2014). Intersegmental Eye-Head-Body Interactions during Complex Whole Body Movements. *PloS one*, 9(4), e95450.