GAZE BEHAVIOUR IN ELITE GYMNASTS WHEN PERFORMING MINI-TRAMPOLINE AND MINI-TRAMPOLINE WITH VAULTING TABLE – A PILOT STUDY

Joana Filipa Pereira de Sousa de Carvalho Barreto[1], Filipe Luís Martins Casanova[2], César José Duarte Peixoto[3]

[1,3] Faculty of Human Kinetics, University of Lisbon, Portugal
[2] Faculty of Sport, University of Porto, Portugal

Case study

Abstract
Visual system provides information from the environment, leading gymnasts to improve performance. The question of what sources of visual information from the environment contribute to performance, remains unclear. This study aims to analyse visual behaviour, as areas of interest, fixated by Teamgym elite gymnasts during the performance of techniques on mini-trampoline and mini-trampoline with vaulting table. We hypothesised that: a) gymnasts would fixate areas of interest in the environment to visually perceive relevant information, b) fixations on the area of interest "landing mat" would occur during the last part of flight phase and landing. Three teamgym elite gymnasts performed three tasks on mini-trampoline and one task on mini-trampoline with vaulting table. The variables were: fixation duration (FD), areas of interest (AOIs), ratio between total fixation duration and total task duration (TFD/TD) and ratio between total fixation duration per AOI and total fixation duration (TFDA/TFD). Results showed that TFD/TD increased with the decreased of complexity degree for all tasks. Mini-trampoline was the most fixated AOI (except for straight barani out on mini-trampoline) while wall was the less fixated. The run-up zone was the most fixated zone. For the task on mini-trampoline with vaulting table, participants reduced the time spent fixating run-up zone and increased time spent fixating mini-trampoline and vaulting table. Landing mat was the only AOI that was fixated during the flight phase. Results suggest that gymnasts may adapt their visual strategy to the degree of complexity of the task, as reflected in the results of TFD/TD and TFDA/TFD.

Keywords: *gymnastics, visual perception, eye-tracker.*

INTRODUCTION

Vision provides information from environment in relation to the person, being part of a cycle where the perception of affordances guides behaviour and behavior discovers new affordances (Gibson, 1986). One of the contexts where this relation can be observed is in sports and, more specifically, gymnastics. The challenge is to analyze visual behavior of gymnasts, in an ecological environment, similar to practice or competition contexts.

Vision is a dominant perceptual system assisting performance (Bardy & Laurent, 1998) on synchronize trampolining (Heinen & Czogalla, 2016), vaulting table (Heinen, Vinken, Jeraj, & Velentzas, 2013) and landing (Davlin, Sands, & Shultz, 2001; Luis & Tremblay, 2008). Also, the positions of springboard and vaulting table influence handspring kinematics (Heinen, Jeraj, Thoeren, & Vinken, 2011), suggesting that gymnasts visually perceive the positions of apparatus to adapt their movement. Such results were also confirmed for Yurchenko technique on vaulting table (Heinen, Brinker, Mack, & Hennig, 2017). Gymnasts perform better landings from back somersaults with full vision during performance, comparing to when vision is manipulated (Davlin et al., 2001). In synchronized trampolining, visual information from the other gymnast's arms seems to be a dominant cue to achieve synchronization (Heinen & Czogalla, 2016). These studies illustrate the importance of visual system to perform in diverse situations in gymnastics sport.

Additionally to studies that revealed the importance of visual system in performing gymnastics, other studies investigated experts versus non-experts. Differences were found regarding the duration and location of fixations (von Lassberg, Beykirch, Campos, & Krug, 2012), (Mann, Williams, Ward, & Janelle, 2007). Experts reveal more significant correlations between gaze behaviour and kinematics of somersault, comparing to novices (Heinen, 2011). Expert gymnasts use visual information to regulate kinematic variables in every phases of movement, as: contact time with apparatus, flight duration, landing deviation and moment of inertia. An interaction between eye, head, spine and joint movements was shown, when gymnasts perform multiple twisting somersaults, pointing to a functional relation that facilitates orientation in space (von Laßberg, Beykirch, Mohler, & Bulthoff, 2014).

Scientific evidences suggest a relationship between visual perception and movement adaptation in gymnastics. However, methodologies were conducted in a non-ecological way, which means that, it differs from practice/competition environments, namely in: similarity of the tasks performed, contextual constraints and in the use of indirect instruments to analyze visual behaviour. Some studies have manipulated visual behaviour by asking the gymnasts to fixate their gaze into a specific area (Heinen, Jeraj, Vinken, & Velentzas, 2012) or have occluded visual (Heinen, Koschnick, Schmidt-Maaß, & Vinken, 2014), (Luis and Tremblay, 2008) and auditory (Heinen et al., 2014) cues from the environment. Other studies measured gaze behaviour indirectly (not using an eye-tracker) and the tasks chosen were performed in isolation and not in a sequence as it is typical in training or competition contexts (Luis and Tremblay, 2008) (Heinen, Walter, Hennig, & Jeraj, 2018), (Davlin et al., 2001), (Bardy & Laurent, 1998), (Sato, Torii, Sasaki, & Heinen, 2017). Although this studies contribute to scientific knowledge in this domain, by evidencing a relationship between gaze behaviour and movement kinematics, analyze visual perception in real environment with direct instruments (ecological perspective), will provide more reliable details on visual patterns and on how gymnasts visually adapt to different contextual constraints.

The aim of this pilot study is to analyse visual behaviour, as areas of interest fixated by Teamgym elite gymnasts during the performance of techniques on mini-trampoline and mini-trampoline with vaulting table.

We hypothesised that: a) gymnasts would fixate areas of interest in the environment to visually perceive relevant information, b) fixations on the area of interest "landing mat" would occur during the last part of flight phase and landing.

METHODS

Three Teamgym elite gymnasts (male, senior elite category, mean age = 21.6 years, SD = 5.4 years) took part in this study. All gymnasts had participated in Teamgym European Championships for the last four years. They reported normal or corrected to normal vision, and signed the informed consent form. They were able to perform the study tasks autonomously and were free from injuries. The study followed the guidelines of the Declaration of Helsinki and had ethical approval from Ethics Committee of Faculty of Human Kinetics (6/2018).

The tasks were performed in i) mini-trampoline and ii) mini-trampoline with vaulting table. Three tasks on mini-trampoline and one task on mini-trampoline with vaulting table were analysed. The tasks included a 25 meters run-up towards the apparatus, the performance of the technique and landing. The techniques on mini-trampoline were: straight barani (SB), tucked barani out (TBO) and straight barani out (SBO). On mini-trampoline with vaulting table, participants performed handspring straight barani out (HSBO).

The tasks were chosen to represent characteristics of Teamgym discipline: 1) the two apparatus are performed in the same competition program (mini-trampoline). This program has a maximal duration of 2’45’’ and the team performs 3 rounds with 6 gymnasts in each round. At least one round is performed with vaulting table. This implies that, in a short period of time, some gymnasts from the team perform in the two apparatus; 2) tasks analysed are similar in regarding movement: the last somersault and the half twist of SBO and HSBO are similar to SB; 3) tasks on mini-trampoline are used as a pedagogical progression to learn other tasks on mini-trampoline and mini-trampoline with vaulting table (example: SB is used as a pedagogical progression to learn the last phase of SBO and HSBO). Additionally, this tasks have body rotations in transversal and longitudinal axis, different body positions (tucked and straight) and an increase in degree of complexity, which makes this analysis richer. Complexity degree (difficulty score in Code of Points, CoP) is determined by degrees of rotation in longitudinal and transversal body axis and body position (Sjostrand, Lemmetty, Hughes, Gryga, & Jónsdóttir, 2019) (Table 1).

The Gymnasium at Faculty of Human Kinetics was prepared with apparatus according to Teamgym Directives from European Union of Gymnastics (UEG) (Sjostrand et al., 2019) (Figure 1).

Tobii Pro Glasses 2 ® was worn by participants during the tasks. The system is a binocular eye tracker that records the point-of-gaze onto a video image of the scene, measuring the relative position of the pupil and corneal reflection. The recording process was undertaken using a Tobii Glasses Controller Software, running on a Dell Venue 11 Pro 7130, Windows 8/8.1 Pro tablet at a rate of 50 Hz. The image is transferred to a computer and analyzed by running the Tobii Glasses Analysis Software: Tobii Pro Lab. Being a direct method to study gaze behaviour, without manipulation of the visual stimulus (e.g. spatial occlusion), Tobii Pro Glasses 2 provided a higher level of ecology and revealed the expertise effects on gaze behaviour and decision-making (Kredel, Vater, Klostermann, & Hossner, 2017).

Participants used a vest with a pocket placed on their back with the record unit. The vest was used under a fit t-shirt, to minimize the displacement of the record unit.

Participants did a twenty-minute warm-up including general aerobic exercises of low intensity, specific exercises related to techniques of the study and some trials on mini-trampoline and mini-trampoline with vaulting table. The warm-up protocol was similar to warm-up in training sessions.

The eye-tracker was fitted onto de participant’s head to perform three familiarization trials. After the adjustments, calibration was made by asking each participant to stand still and to fixate a target on the centre of the calibration card, at a distance of approximately 1.25 meters during 5 seconds. After calibration, to ensure the best quality of data, we asked the subjects to look to five different points in the environment. The five points were part of AOIs and were at various distances, heights and widths of the subject. Besides this procedure is recommended, it gives us an idea if the calibration is good or if there is a necessity to repeat it.

Participants performed three trials of each technique, starting on mini-trampoline. They were encouraged to perform tasks as in a competition. Intervals between twenty to forty seconds between trials allowed to verify the eye-tracker and to recalibrate when necessary.

The gaze data were analysed frame by frame (sampling rate of 50Hz). Three gaze behaviour variables were considered for this study: number of fixations (NF), fixation duration (FD) and AOIs.

A fixation was considered when gaze remained stationary for at least 99.99 milliseconds (Vickers, 1992), with a tolerance of 0.5º (Williams, Davids, & Williams, 2005). An Area of Interest/visual reference point is an area/object from the environment (for example, the mini-trampoline) that is visually relevant for the participant when performing these tasks. Visual behaviour was analysed to calculate the percentage of viewing time, dividing the total fixations duration by task duration (ratio TFD/TD) and dividing the total fixations duration per AOI by total fixations duration (ratio TFDA/TFD).

In this study, seven AOI were defined previously to analysis, based on objects that the participants need to physically contact to perform the tasks. Also, AOIs where the subject possibly would search for visual information were included (example: front and lateral walls). Lastly, “undefined” was considered an AOI in case any participant fixate an area not considered in the others. The seven AOIs considered were: a) 1st part of run-up, b) 2nd part of run-up, c) hurdle, d) mini-trampoline, e) vaulting table, f) landing mat, g) front and lateral walls and h) undefined. 1st and 2nd parts of run-up were 10 meters long and 2 meters large each, while hurdle which is the zone were gymnasts did the last foot contact with floor, were five meters long and 2 meters large. Landing mat was 4 meters large and 7 meters length. Wall was considered as the front and lateral walls and undefined was categorized when the fixation was not in any of the mentioned AOIs (Figure 1).

Since this is a pilot study with an exploratory approach, with a small sample size and few repetitions, it was statistically underpowered, and only descriptive statistics were used (Field, 2018).

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Table 1
Complexity degree/Difficulty value for tasks analysed according to 2017-2021 Teamgym Code of Points - Juniors and Seniors.

Task	Straight barani (SB)	Tucked barani out (TBO)	Straight barani out (SBO)	Handspring straight barani out (HSBO)
Complexity degree/ Difficulty value	0.30	0.70	0.90	1.10

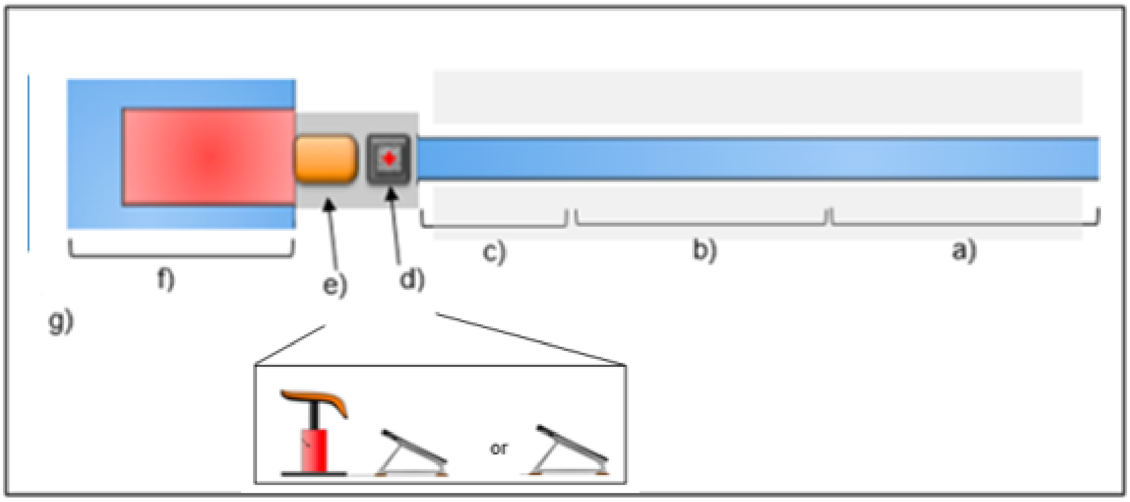

Figure 1. Apparatus setup and Areas of Interest considered for analysis: a) 1st part of run-up (10 x 2 meters), b) 2nd part of run-up (10 x 2 meters), c) hurdle (5 x 2 meters), d) mini-trampoline, e) vaulting table, f) landing mat (4 x 7 meters), blue line) front and lateral walls. Lateral detailed view for apparatus and AOI: d) mini-trampoline and e) vaulting table

Table 2
Characteristics of tasks: difficulty value according to Teamgym Code of Points, total task duration and fixations characteristics during the four different tasks: total fixation duration and ratio between total fixation duration and total task duration (m ± SD)

Complexity degree (CoP)	Task	Total task duration (sec)	Total fixation duration (sec)	Ratio Total Fixation Duration / Total Task Duration (%)
0.30	1 - Straight barani (SB)	5.85±0.41	2.86±0.71	48.88±12.30
0.70	2 - Tucked barani out (TBO)	5.98±0.48	2.52±0.53	42.14±9.04
0.90	3 - Straight barani out (SBO)	6.49±0.46	2.39±0.39	36.83±2.99
1.10	4 - Handspring straight barani out (HSBO)	4.73±0.13	1.15±0.48	24.31±10.70

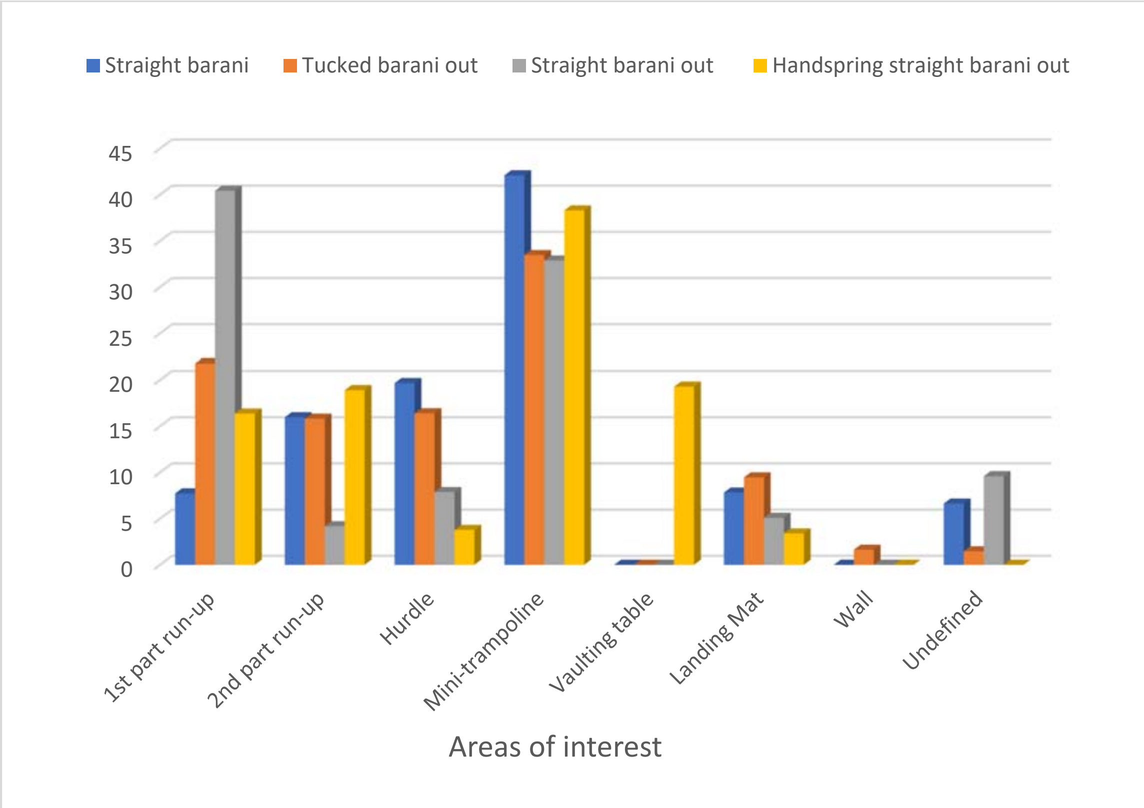

Figure 2. Ratio between Total fixation duration per AOI and Total fixation duration during the task (%).

RESULTS

Ecological validity. This pilot study aim to analyse visual behaviour, as areas of interest fixated by Teamgym elite gymnasts during the performance of techniques on mini-trampoline and mini-trampoline with vaulting table.

However, we think it is important to point out some aspects about the equipment: Tobii Pro Glasses 2 was able to collect gaze behaviour data during almost the entire tasks, except for small periods of time after the last contact with mini-trampoline or vaulting table and before landing, during rotations in transversal body axis were performed. It is an ecological instrument, allowing to study gaze behaviour in real context. It reveals to be easy for subjects to adapt to it, even if they never used glasses. The preparation of the subjects and calibration of the eye-tracker, takes between five to ten minutes. The investigator should guarantee that the calibration has the best quality possible, since it can affect data quality. Data analysis is time consuming process, which is a disadvantage for the investigator.

Number of fixations. Despite number of fixations can be an individualized parameter (Williams et al., 2005), we found smaller ranges for SBO and HSBO with values between 1-3 and 3-6 respectively. Contrary, we observed a larger range between 3-12 fixations for SB, and 2-13 for TBO.

Ratio Total fixation duration/ Total task duration (%). Ratio between total fixation duration and total task duration (TFD/TD) decreases with the increase in complexity degree for all tasks (see Table 2). For the less complex task (SB), participants spent approximately half of the time fixating AOIs (48.88±12.30%), while for the most complex task on mini-trampoline (SBO) participants spent approximately 36.83±2.99% of the total task duration fixating AOIs.

For the task on mini-trampoline with vaulting table (HSBO), with the higher complexity degree of all tasks analysed, participants spent 24.31±10.70% of the total task duration fixating AOIs (Table 2).

Ratio between Total fixation duration per AOI and total fixation duration (%). The most visited AOI was mini-trampoline for all tasks (relative percentage of 36.69%), followed by 1st part of run-up (21.57%) and vaulting table (19,28%). The less visited AOI was the wall (0.41%) that we considered as the front and side walls of the gymnasium. Although landing mat was not the less fixated AOI (6.44%), we expected that we would find higher values for this AOI (see Figure 2).

The run-up zone together (1st part, 2nd part and hurdle) registered the highest TFDA/TFD values, demonstrating the importance of this AOIs for visual perception and performance of the tasks analysed.

Mini-trampoline vs Mini-trampoline with vaulting table. For tasks on mini-trampoline (SB, TBO, SBO) values for TFDA/TFD between 32.87% and 42.09% were registered for the AOI mini-trampoline (the only apparatus). When performing HSBO, mini-trampoline and vaulting table together represented 57.58% of the time spent fixating AOIs, with a higher value for mini-trampoline (38,30%). Participants spent less time fixating run-up zone (39.04%) and more time fixating both apparatus (57.58%) for HSBO.

AOI fixated before flight phase vs during flight phase and landing. 1st part, 2nd part, hurdle, mini-trampoline, vaulting table and wall were fixated before the beginning of flight phase. Landing mat was fixated during contact with mini-trampoline until landing and, after last contact with vaulting table until landing. Undefined AOI were fixated during run-up.

DISCUSSION

This study analyses visual behaviour, namely areas of interest fixated, as mini-trampoline and vaulting table, by Teamgym elite gymnasts during the performance of techniques on mini-trampoline and mini-trampoline with vaulting table.

One main result of this study is that TFD/TD decreases when complexity degree increases for all tasks, which means that, when performing more complex techniques on mini-trampoline and mini-trampoline with vaulting table, participants tend to spend less time fixating AOIs (Table 2). First, this result can be due to the characteristics of the analysed tasks: the greater the complexity of the task, the more difficult it is to perform it, since gymnasts have to control more variables. This maybe indicates that gymnasts rely less in visual information and more on other sensory systems during more complex tasks. Additionally, during complex tasks, gymnasts increase velocity during run-up to produce strength during contact with mini-trampoline, resulting in higher and longer flight phases (Fernandes, Carrara, Serrão, Amadio, & Mochizuki, 2016). These higher and longer flight phases ensure that the gymnasts had enough time to perform the entire technique before landing (Fernandes et al., 2016). On the other hand, less complex tasks have the particularity that gymnasts had repeated it much more times during their practices, meaning that they have more control and possibly utilize more visual information rather than other sensory systems. In the most complex tasks on mini-trampoline and mini-trampoline with vaulting table (TBO, SBO and HSBO), participants known, due to experience, that there were certain phases of movement (flight phase) that they cannot fixate AOIs, due to body velocity. This fact led them to be more effective in selecting to where to look and for how long, in order to pick the relevant visual information (Raab, de Oliveira, & Heinen, 2009). Heinen et al., (2018) concluded that an increased in spatial orientation ability results from an optimized processing of sensory information that is dependent on gymnasts' experience. This supports that during flight phase, elite gymnasts may use other senses to obtain spatial information when vision is not available.

We expected to observe a higher value for TFD/TD (24.31±10.70%) during HSBO. Since the tasks were performed successfully, we can assume that these participants were more efficient in perceiving information from the environment, resulting in a low TFD/TD value but in an effective visual strategy, acquired with the experience.

Time spent fixating the 1st part of run-up increased with complexity degree of tasks performed on mini-trampoline. From what participants verbally reported and what we observed on data, participants tend to look down during the first steps of run-up, not to withdraw visual information but as a mechanism to focus on the task, which seems to be related with complexity degree. Several studies have proved that position of springboard (equivalent to mini-trampoline in Teamgym) and vaulting table were relevant for performance, influencing feet position during run-up and hands position during contact with vaulting table (Thomas Heinen et al., 2013; Heinen, Jeraj, Thoeren, & Vinken, 2011). This is in accordance with our results, showing higher values of TFDA/TFD for mini-trampoline. We suggest that, for being the first apparatus to visually contact, mini-trampoline it is the most important source of visual information to regulate velocity, length of steps, impulse and also time to contact with mini-trampoline and vaulting table (Lee, Lishman, & Thomson, 1982). Even though TFDA/TFD values for landing mat are lower than expected, fixations in this AOI occur during the longitudinal body axis rotation, at the end of flight phase. Higher TFDA/TFD values for landing mat during TBO when the body is in a tucked position (i.e. knees in front of the face), may reflect the less level of visibility in this task, when comparing with tasks in straight body position, and the need to search for visual information in the last part of flight phase. In addition, a lateral rotation of their heads previous to the longitudinal rotation of the body is perceptible. This head movement occur even for SBO where no fixations on landing mat were registered. Despite there is no investigations, we think that there might be two reasons for this factor: a) the head lateral movement occurs as a natural movement of the body to start the rotation on longitudinal body axis; b) it occurs as an attempt to visually perceive information about the landing mat, allowing participants to orientate themselves in space and time. Participants mentioned that they try to look at the landing mat when they start the rotation on longitudinal body axis, to help them to anticipate landing. However, even that fixations on landing mat were registered for some tasks, it is not possible to say if they can perceive visual information from the landing mat in a short period of time, and if yes, what information was perceived, and how it helped gymnasts to adjust their motor actions.

We observed that, when comparing tasks performed on mini-trampoline and mini-trampoline with vaulting table, participants reduced the time spent fixating the three areas of run-up to spend more time fixating mini-trampoline and vaulting table (TFDA/TFD = 39.04% for run-up areas on mini-trampoline versus 57.58% on mini-trampoline and vaulting table). We can be in the presence of a strategy to use the relevant sources of visual information when an apparatus (vaulting table) is added. Despite mini-trampoline continues to be the most fixated apparatus, it seems that participants fixated vaulting table to adjust their motor actions, meaning that vaulting table could influence run-up phase.

Finally, the majority of time spent fixating AOI occurred before flight phase. We propose that this result was due to the larger time spent on run-up, which reinforces the importance of this phase to visually perceive the environment and to adapt the movement.

Since this is a pilot study, we would like to leave some notes and questions. First of all, about the eye-tracker Tobii Pro Glasses 2, since this kind of equipment is rarely used in gymnastics. The eye-tracker Tobii Pro Glasses 2 was able to collect gaze data with limitations when the rotational body velocities reach high values. Several reasons can cause this problem: eye blinks, looking down in a way that the system can not identify the pupils or due to the movement of the eye tracker relative to participant's face. We recommend that future studies analyse eyes images during tasks, and that investigators be sure that the eye tracker is well fixed to the participant's face. Also, we advise investigators to ensure a good calibration procedure (as described in methods - procedures) to guarantee the data quality, and to analyse raw data since there is no evidence for the suitability of other filters included in the software. A balance between external validity of the experimental conditions (ecology) and the reliability of the measurements is essential (Kredel et al., 2017).

Second, some questions were raise during this study that we recommend to be taken into account in future research:

- Can we observe a consistent visual pattern regarding variables analysed in individual elite gymnasts, when repeating the same task? (intra-subject analysis)
- How is visual behavior related with body kinematics as velocity, step length during run-up, movement of the arms during contact with mini-trampoline and vaulting table?

We believe that research in this field of study will provide precise conclusions and will allow to give recommendations to coaches working with gymnasts of any level of expertise.

CONCLUSIONS

The results of this pilot study, being acknowledged of its limitations (sample size and number of repetitions performed), lead to questions on visual perception of elite gymnasts. We suggested that investigators analyse visual perception in gymnastics to understand visual strategies and visual references, in order to give recommendations to help gymnasts and coaches improving performance. The importance of future studies in this field relies on encourage gymnasts to use relevant visual information from the environment, that could assisted them in becoming more efficient and successful in practising and learning new techniques.

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Corresponding author:

Joana Barreto
Faculty of Human Kinetics, University of Lisbon
Estrada da Costa 1499-002 Cruz Quebrada – Dafundo, Portugal
E-mail: jcbarreto@fmh.ulisboa.pt
Telephone and fax: : 00351 910213883

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