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Original Article

Constraining of peripheral vision reduces standing long jump performance in children

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Abstract:
Peripheral vision appears to be more important than central vision for tasks where precision or ocular coordination are essential. To determine whether this effect is observedwhile performing a task for which precision is not critical, the performance of 34 children (6–9 years old) in standing long jumpwastested. Adapted swimming goggles, which induced different levels of constraint of field of vision,were used to provide full field vision, restrictthe use of central vision, and restrict the use of peripheral vision. The obtained results showed a strong detrimental effect onstanding horizontal jump length (both best and mean results) when the peripheral field of vision was restricted (approximately 5% less; $p < 0.001$). However, thedetrimental effect was not observed when only the central field of vision was absent. These results indicatethat peripheral vision is essentialfor this locomotor task. Although standing long jump canbe considered as a non-precision task, the children tested were able to jump farther both when vision was not restricted and when peripheral vision was allowed. A reasonable explanation is that the absence of access to optic flow detection inhibits normal motor behaviour perhaps owing to worse posture and stability. The obtainedresults suggest that information that arrives through peripheral vision is more important for jumping performance thaninformation from central vision. Furthermore, jumping biomechanics may be more hampered by the absence of these peripheral stimuli than by the impossibility of gazing straight inthe jumping direction.Thus, it is reasonable to conclude that special attention should be paid to the use of peripheral vision in physical activity tasks.
Keywords: **constraints; perception–action coupling; peripheral stimuli; postural stability**

Introduction

While it is clear that vision is essential formost human motor tasks, the importance of central versus peripheral vision remains unclear. Matos et al. (2019c) have studied the contribution of central and peripheral vision inyoung swimmers. The results showedthat the performance of attempting to maintain a travel line parallel to strings separating tracks was significantly impaired when using glasses that completely restricted the use of vision. However, this result was not obtainedwhen only peripheral or central vision wererestricted. The authors concluded that peripheral and central vision by themselves were sufficient to maintain swimming performance for thecrawl technique without major lateral deviation.

Peripheral vision and division of attention appear to be essential in team sports (Matos, 2016). Inindividual sports, the importance of peripheral vision has been also highlighted. In fact, recently,Hausegger, Vater, and Hossner (2019) have observed this effect inmartial arts and showed how experts used gaze anchoring to optimize the use of peripheral vision information. In addition, adults have higher performance instanding height jump under thefull-vision condition than without vision (Abdollahipour, Psotta, & Land, 2016). However, children and adults navigate adaptively without frequent obstacle fixation, which means that they rely on peripheral information or memory (Franchak& Adolph, 2010). It is also known that,typically, elite athletes have better-developed fields of vision than their non-elite counterparts (Matos et al., 2019b). Contrary to common sense, the role of central vision may be less important than previously thought, whereas peripheral vision maybe essential (Matos, 2018). In addition, it appears thatthere may be an age-related progress in visually guided locomotion. From infancy to adulthood, there is a considerableshift from foveal to peripheral control because infants fixated 72% of obstacles, children fixated 59%, and adults fixated 32% (Franchak& Adolph, 2010).

Previous studies provide various examples on the effects induced by visual restriction. For example, basketball throw was not affected by a decrease in visual acuity induced by optical blur (Applegate & Applegate, 1992). However, higher sport performance (discus and javelin throwing, slalom skiing, and ice skating) wasmore dependent on peripheral visual information than on fovealone (Graybiel, Jokl, & Trapp, 1955). These results support the idea that peripheral vision is critical for self-motion perception (Dichgans& Brandt, 1978). Using

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competitive long jump as an example, it has been determined that athletes decrease their jump length (Eves, 1995) and their variability in stride length (Eves, Gillham, Challis, Shepherd, & Li, 1996) when their peripheral vision was restricted. Therefore, it canbe assumed that long jumpers also rely on peripheral vision to regulate their approach to the take-off board. Those final adjustments in the last strides prior to take-off showedthat various motor tasks werevisually monitored during the execution and late phase of implementation (Lee, 1980; Lee, Lishman, & Thomson, 1982).

Despite the abovementioned statements and the fact that peripheral vision appears to have a more relevant contribution, these results remain poorly understood. As several authors have indicated(Abernethy, 1988; Egeth& Yantis, 1997; Williams &Davids, 1998), attention can be reallocated in the visual field without producing distinguishable eye movements. Specifically, thesubject may look at a specific point or target but extract information from the periphery (Klostermann, Vater, &Kredel, 2016). For example, Rienhoff, Baker, Fischer, Strauss, and Schorer (2012) have created an experimental design to clearly identify the contribution of peripheral and central vision tounderstand the quiet eye period. Thus, they examined skilled and less-skilled dart players. However, becausetheir experimental design only removed peripheral or central areason the target, doubts still remain. Subjects were able to continuously watch their throwing arm inthe absence of peripheral vision becauseonly the peripheral area surrounding the bull's-eye of the target and not the peripheral visual field itself was occluded. Nevertheless, the authors concludedthat the higher accuracy performance inthese types of tasks could have been due to better postural stability rather than perceptual factors.

Regarding postural stability, a stable standing posture is more closely associated with peripheral than central vision (Berencsi, Ishihara, &Imanaka, 2005). Cao & Händel (2019) have also determined that walking enhances peripheral visual processing in humans with a concomitant decrease incentral visual processing. Authié, Berthoz, Sahel, &Safran (2017) and Peli, Apfelbaum, Berson, & Goldstein (2016) have stated that adults with retinitis pigmentosa experience a loss inperipheral visual field, which accounts for most difficulties encountered in visuo-motor coordination during locomotion. Therefore, it isclear that some aspectsof vision are essential not only for precision but also for body control.This reason may explain why Matos et al. (2019a) have concluded that the absence of peripheral vision availability results in significantly higher intra-variability (i.e., higher coefficient of variation) compared with the situation when central visionis absent. Thus, when peripheral vision is restricted, jumping performance becomes less consistent.Matthis, Yates, &Hayhoe (2018) have determined that it is likely that peripheral vision alone is sufficient forwalking on flat terrains. Of note, human beings are not the only species who can use covert attention (peripheral vision) for mobility processes. This resulthasbeen recentlyconfirmed by Yorzinski (2019) while examining eye movements of female peahens. The author suggested that peahens likely relied on peripheral vision to guide their jumping actions. Other studies have also provided several examples of the importance of peripheral vision. Matos and Antunes (2018) have provided a valuable insight into how choral singing may benefit from an increased use of peripheral vision.

Thus, we speculate that peripheral vision may be essential even fortasks where precision is not the major focus or when final adjustments are not required. The aim of this study was to examine whether peripheral vision was essential in children's standing long jump performance. It was hypothesized that jumping length would decreasewhen peripheral vision was occluded.

Materials and methods

Participants

A total of 34children (18 girls and 16 boys; 7.5 ±0.6-years-old; 124.9 ±5.6-cm height; 25.8 ±3.81-kg body mass) were recruited to participate in the experiments. All subjects reported no motor or perceptual conditions and none of the subjects wore glasses. The study was conducted in accordance with the Declaration of Helsinki for research involving human participants. The Institutional Ethics Committee approved all experimental procedures. Parents' consent and children's assent through the intervention of their primary teachers (who were present during data collection procedures) were obtainedprior to the experiments.

Procedures

Subjects performed a total of 9 standing long jumps, i.e.,3 trials for each of 3 conditions:

a) No vision restriction

b) Only central visionwas allowed

c) Only peripheral visionwas allowed

Data were collected without awarm-upby asking the children to jump as far as they could. A sportive garment was requested to be worn, and no demonstration was provided. If forsome reason the jump was not valid, the trial was repeated. A rectangular tape (5-cm wide, 60-cm long) was fixed to the ground, and the jumping distance was measured from the posterior point of the feet on that tape.

For each subject, a data registration sheet was prepared, directinghim/her to perform one ofsix possible sequences among the jumping conditions. This approach allowed tocounterbalancesixpossible sequences, which minimized any learning and warm-up effects. After performing 3 jumps under first condition, the subjects changed to the next condition, and then to the last one by following thepredefined order in the data registration sheet.

Adapted swimming goggles were employedto restrict visual input (Sivak& Mackenzie, 1992). Three types of swimming glasses (approximately 15-mmdistance from lenses to eyes) were used (Figure 1): a)without modifications (to have a common basis for subsequent jumps), b) with black tape occlusion except fora central 5-mm diameter circle (allowingapproximately 10° of central vision, with peripheral vision restricted), and c) with a black vertical tape rectangle (30-mm height, 12-mm width)occluding central visual field (approximately 20°). The restriction of field of vision was determined by a tangent perimetry procedure.

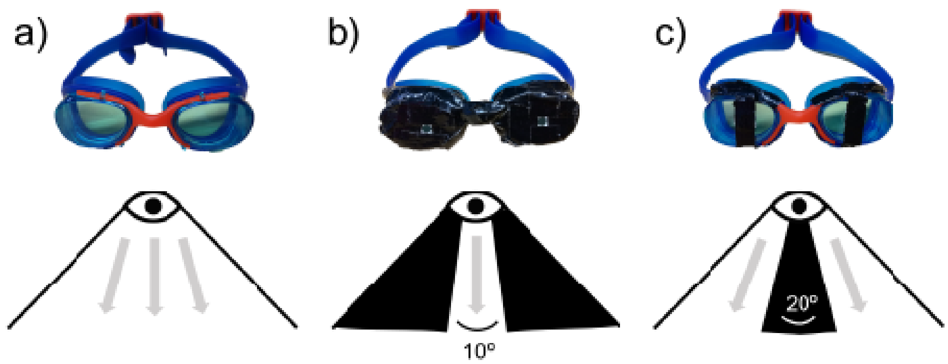

Figure 1. Adapted swimming googles, which allowed full vision (panel a), central vision (panel b), and peripheral vision (panel c)

During a pilot study, we useda 12-mm diameter black tape circle to occlude the central visual field. However, we could not ensure that this occlusion really prevented the use of central vision. First, there was a lack of adaptability. In fact, the mark could be central for one subject but not for another becausepeople have different heads and distance between eyes. Therefore, in this experiment, we used*peripheral vision* condition goggles, which could be adjusted according to the distance between eyes. Second, we could not be sure that subjects would not look over or under the central black circle when moving their heads, thus maintaining the possibility of central vision use. Thus, we extended the occlusion of the central visual field with a black vertical tape rectangle that was superimposed on the original black tape circle. This approach ensured that children could not look over or under the central circle.

Data analysis

For each of three jumping conditions, two parameters were analysed: best performance (the longest of the 3 trials) and average performance (the mean of the 3 trials).

Statistical analysis

Sample size was estimated for repeated measures design, with a significance level of 0.05 and an expected observed power of 0.80. Variables were expressed as means and standard deviations. After normality and homoscedasticity assumption were confirmed (by Shapiro–Wilk and Levene tests, respectively), the factorial analysis of repeated measures was used. Post hoc analysis (Bonferroni), effect size (partial eta squared), and power (1-β) for obtained differences were calculated. Statistical procedures were performed using SPSS v23.0 for Windows® (Chicago, IL) and G-Power 3.1.9.2 for Windows® (University of Kiel, Germany). The level of statistical significance was set at $p < 0.05$.

Results

The results for the best and average performance for three conditions are shownin Table 1. Lower performances were obtained when children had their peripheral vision limited.

Table 1

Best and Average Performances underDifferent Standing Long Jump Visual Conditions

	Full vision allowed	**Only central vision allowed**	**Only peripheral vision allowed**	***p***	η_p^2	**1-β**
Best performance (cm)	118.9 ±19.5	114.0 ±19.8	118.4 ±19.8	0.001	0.370	0.967
Average performance (cm)	112.7 ±19.7	106.8 ±18.9	114.0 ±19.5	<0.001	0.584	1.000

Post hoc analysis demonstrated that constraining of peripheral vision (i.e., only central vision allowed) had a strong (detrimental) effect on jumping performance, both best (Figure 2, panel a) and average (Figure 2, panel b). In addition, no differences were observed between jumps with full vision and with peripheral vision.

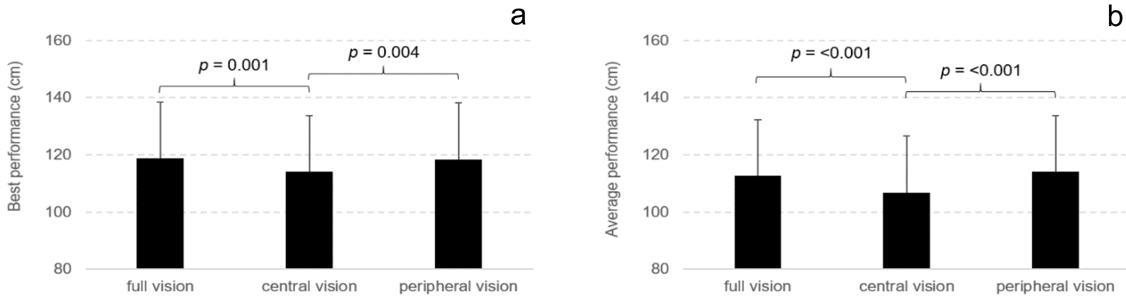

Figure 2. Post hoc analysis ofbest (a) and average (b) standing long jump performances

Discussion

This study aimed to examine whether peripheral vision was essential forchildren's standing long jump performance. Inprevious studies on motor tasks for which precision or ocular coordination werecritical, the relevant role of peripheral vision was observed. Specifically,in long jump, people regulate their approach to the take-off board by relying more on peripheral than central vision. However, standing long jump is not a task for which closed-loop feedback appears to be essential. Nevertheless, it isrelevant to investigate whether the importance of peripheral vision occursfor this particular task.

Obtained results corroborate previous experiments onadults (Dichgans& Brandt, 1978; Eves, 1995; Graybiel et al., 1955). A nonsignificant reduction of ~1% was observedinlong jump performance when peripheral vision was allowed. However, jump performance decreased by ~5% when peripheral vision was restricted (Eves et al., 1996). In this study, no differences were observed between jumps with full and peripheral vision. Similarly, children's jump length decreased by ~5% when peripheral vision was restricted. The obtained jumping distances were similar to the normative Portuguese data for subjects of the same age (Oliveira, Seabra, Freitas, Eisenmann, & Maia, 2014). At 7.5 years of age, children have the50th percentile of 112 cm for boys and 100 cm for girls.

The obtained results clearly confirm the essential role of peripheral vision in this locomotor task. Peripheral vision optic flow detection may explain this observation well; though, uncertainties remain about its direct use (Franchak& Adolph, 2010) and its indirect role through postural stabilization (Berencsi et al., 2005). Researchers have been interested for a long timein the role of quiet eye in motor tasks(de Oliveira, 2007; Vickers, 2016). Apart from being relevant for capturing information for acting, it may be also essential for postural stability (Rienhoff et al., 2012). Thus, in addition tousing peripheral vision for detecting important environmental cues that are perceptually decisive for good performance, peripheral vision may also allow a biomechanically more advantageous starting point for action. In addition, quiet eye period and its long final fixation may be useful forsituations that require an "anchoring strategy", i.e.,situations where it is beneficial to use a pivot-point strategy (Klostermann, Vater, &Kredel, 2016). When this strategy was used, children were able to obtain information from single fixation and choose the best movement option.

Furthermore, the results agree with those of Franchak and Adolph (2010), who determinedthat children (and adults) navigated adaptively without frequent obstacle fixation. Nevertheless, the authors indicatedthat there was an age-related progress in visually guided locomotion from infancy to adulthood. Their experiments showed that infants fixated more obstacles than children, and children fixated more obstacles than adults. The authors suggested that peripheral vision, along with memory, could justify this lifespan shift. Thus, additional research is needed todetermine which peripheral vision components (vertical/horizontal meridians) are essentialfor this motor task. Finally, it maybe interesting to determine if the common figure (approximately 5%) obtained in this study and that of Eves et al. (1996) will also occur forother tasks (e.g., standing height jumporoverarm throwing).

Furthermore, the restrictions that the subjects of our study experienced may be similar to those reported by Authié et al. (2017) and Peli et al. (2016). In fact, although taking in account that these authors studied adults, all subjects suffered from retinitis pigmentosa and experienced a loss of peripheral visual field, which we *simulated* in our study. Theresearchersstated that the diminished peripheral vision use accounted for most difficulties encountered in visuo-motor coordination during locomotion. In our study, we also observed the abovementioned detrimental effects in a locomotor pattern, i.e., standing long jump.

Onelimitation of this study is that we did not control the length of time a child stood at the line prior to the jumping action. This factor could have given us an indication about the potential use of quiet eye period for both conditions. As a matter of fact, sinceperipheral vision conditiondid not allowchildren to fixate the spot where to jump, we might have expected a negative effect on performance, which was not the case. The obtained results suggest that the information that arrives through peripheral vision is more important than gazing onto a virtual self-determined target with respect to where to jump (maximal jumping distance self-perception). Thus, we may conclude that peripheral vision will enable subjects to assume better postures, increase body stability, and enhance optic flow capture. We speculate that jumping biomechanics may be hampered more by the absence of these peripheral stimuli than by the impossibility of gazing straight in the jumping direction. In subsequent studies, it may be interesting to evaluate standing long jump biomechanical changes forthese two typesof perceptual constraints using kinetic and kinematical analyses.

Conclusions

On the basis of previous studies on the same subject, our results showed that peripheral vision was more important than central vision forstanding long jump performance in children. Actually, a detrimental effect onstanding horizontal jump performance was observedwhen subjects were prevented from using their peripheral field of vision. However, negative effect was not observed when only the central visual field was absent. Although jumping biomechanics was not analysed, it was possible that by preventing the use of peripheral stimuli, postural and jumping dynamics issuesoccurred that negatively affected jumping distance performance.

Thus, it isreasonable to conclude that special attention should be paid to the use of peripheral vision inphysical activity tasks. Physical Education teachers, trainers, and other sports experts must be aware of this and, accordingly, help children acquire and use visual strategies when peripheral vision is essential. An example of these strategies will be the so-called anchor strategy, where people gaze at a fixed point to extract relevant information from its periphery. Using this strategy, several different stimuli can be detected at a glance. Furthermore, fixed gaze seems to have, as has been previously stated, positive effects on posture, stability, and optical flow capture. Of note, central vision seems to be more important for peripheral detection from a stable point than for its own visual functioning. Head stability while capturing peripheral stimuli may be the key because this detection is diminished when eyes continuously move owing to the so-called saccadic suppression.

Professionals should be aware that, with age, there is an enhanced capacity of using peripheral control whenmoving around. Therefore, with age, people begin to use more clues that arise from peripheral parts of their field of vision. If they are prevented from using this capability, their performance may be negatively affected.

Thus, the obtained results allow us to conclude that: i) peripheral vision is critical for standing long jump performance in children; when children cannot use it, they jump significantly shorter distances, and ii) the restriction of central vision does not lowerthe standing long jump performance in children.

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Conflicts of interest: none

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