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OBSTACLE CROSSING: DIFFERENT STRATEGIES IN PEOPLE WITH VISION, BLINDFOLDED OR BLIND

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SUMMARY

During obstacle crossing, a minimal vertical distance between foot and obstacle (toe clearance) has to be preserved to avoid tripping. This study analyzed the control of an obstacle crossing task as a reaching motion with the foot when visual information was unavailable to blind and sighted participants. A major difference with upper limb reaching is that the lower limb task has to be integrated with the gait task. In this work we will focus on the control of the trajectory of the lower limb end point (the foot) while the base point of the kinematic chain (the hip) is moving over the obstacle. We hypothesized that vision contributes to estimate the body location with respect to the obstacle while proprioceptive information is sufficient to provide adequate toe-clearance. Seven blind and seven sighted participants (with vision available and blindfolded) walked along a flat pathway and crossed the obstacle 30 times as their lower limb kinematics was recorded. Significant differences in the variables related to the hip position and velocity were observed; the relative distance between hip and foot at critical time, normalized to the subject's height, revealed a distinct behavior between the lack of vision and the vision conditions in both antero-posterior and vertical axes. Results suggest that prolonged lack of vision generates a different strategy to negotiate obstacles. This is a strategy that is probably associated to a lower energy cost.

INTRODUCTION

During obstacle crossing, a minimal vertical distance between foot and obstacle top (toe clearance) has to be preserved to avoid tripping and fall. It is important to note that crossing obstacles in a safe and efficient manner requires both visual and proprioceptive information as body configuration with respect to the environment is continuously changing [1,2]. Blind individuals extract ambient information only via auditory and proprioceptive senses in order to detect the surrounding characteristics and generate the respective mental maps. Based on these mappings blind individuals are able to organize, store and recover relevant information from the environment to make obstacle crossing possible [3]. However, as reported in [4] most of the errors in blindfolded people occur due to foot placement errors in the step before the obstacle and not due to errors in foot elevation. Traditionally, the control of gait has been studied in a different way of that in pointing and reaching tasks with the upper limbs. In this context, the purpose of this study was to analyze the control of an obstacle crossing task as a reaching motion with the foot. A major difference with upper limb reaching is that the lower limb task has to be integrated with the gait task. This implies more requirements to the task, such as maintaining gait stability while displacing the body.

In this work we will focus on the control of the trajectory of the lower limb end point (the foot) while the base point of the kinematic chain (the hip) is moving over the obstacle. More specifically, we hypothesized that vision contributes to estimate the body location with respect to the obstacle while proprioceptive information is sufficient to provide adequate toe-clearance.

METHODS

Seven blind participants and seven participants with normal vision volunteered in the present study. Blind participants were classified as type B1 in accordance to the International Blind Sport Federation (IBSA) criteria. B1 class includes individuals in the range from no light perception in either eye to light perception, but inability to recognize the shape of a hand at any distance or in any direction. Normal and blind participants were age and height-matched. They had, respectively, mean age of 39.3 (SD = 11.5) and 39.3 (SD = 11.7) years and mean height of 173.8 (SD = 4.9) and 172.1 (SD = 8.0) cm. The obstacle height was 26 cm that represented between 30.4% and 32.9% of the leg length of the volunteers. All participants provided informed consent before taking part and the testing was conducted according to the ethical guidelines of the São Paulo State University.

A digital video camera (Sony DCR DVD 205) registered the motion of the markers placed in anatomical landmarks corded participants performing the task. The software Ariel Performance Analysis System (Ariel Dynamics Inc., 1998 – version 1) was used for a two-dimensional kinematical analysis. Matlab (The Mathworks Inc.) and Statistical Package for Social Sciences (SPSS Inc.) softwares were used for further calculations and statistical analyses.

All participants walked barefoot along a five meter pathway with a 26 cm height obstacle located at 3 m from the start. The seven participants with normal vision crossed the obstacle successfully 30 times while blindfolded and with vision (eyes open) conditions. The seven blind participants did the same 30 times. Gait speed was self-selected. Blind and blindfolded participants were allowed to explore the experimental environment, walking and touching the obstacle, prior starting and between trials. Leading limb hip, knee, ankle and foot positions, velocities as well as the joint angles and angular velocities were obtained directly from the data. The values of these variables at the instant of obstacle crossing (critical time) were retained for further analysis. A planar three-link model of the leg was used to calculate the Jacobian with respect to the hip joint. Using this information, the manipulability matrix at the critical time was calculated and the orientation of the ellipse and the values of the principal axes were retained for further analyses. Analyses of variance considering the visual condition (vision, blindfolded or blind) as factor were performed. Finally, the distance between the hip and the foot in the antero-posterior and vertical axes was normalized and retained for analyses.

RESULTS AND DISCUSSION

No statistically significant differences were found either in the orientation of the manipulability matrix or in the magnitude of the principal axes. There are significant differences in the variables related to the hip position and velocity. In particular, the relative distance between hip and foot at critical time, normalized to the subject's height, revealed a distinct behaviour between the lack of vision (Blind and Blindfolded) and the vision conditions (Figure 1) in both antero-posterior and vertical axes.

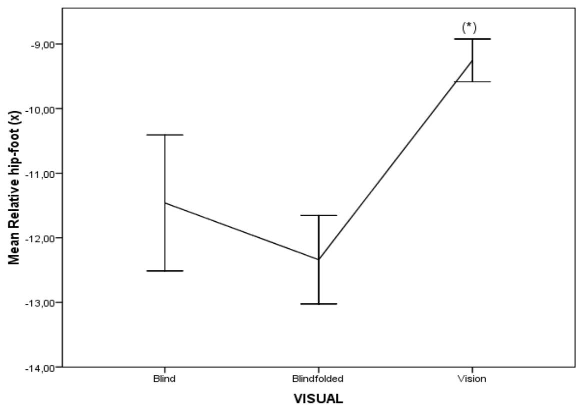

Figure 1: Relative distance in the anteroposterior axis between hip and foot at critical time, normalized to the subject's height. The figure shows the mean and 95% confidence interval for the mean. The asterisk indicates statistically significant differences.

This parameter is useful to evaluate in which way the subject approaches the obstacle. It is negative because the hip is behind the foot of the leading leg. However, it is clear that without vision the foot is more "forward" than the hip. This suggests a clear difference in the strategy to negotiate the obstacle with or without vision. The positions of the hip and foot in the vertical axis showed, at critical time and normalized with respect to subject height revealed interesting differences between groups. The vertical hip position significantly higher for the blindfolded group, and had very similar values for the blind participants and the subjects with normal vision. However, the vertical foot position, again normalized to the height of the subject was significantly smaller for the group with vision. These facts indicate that without vision the needed toe clearance is overestimated. However, it seems that people without vision (blind group) have developed an strategy to avoid an excessive hip elevation. This could be related to the energy cost of raising the body as pointed out previously [5].

CONCLUSIONS

The results suggest that prolonged lack of vision results in a different strategy to negotiate obstacles. This is a strategy that is probably associated to a lower energy cost. Further analyses including multiple analyses of variance (MANOVA) considering the position of hip, knee and foot on the sagittal plane are being carried out.

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REFERENCES

1. Gibson JJ. *The ecological approach to visual perception*. Hillsdale, NJ: Lawrence Erlbaum Associates, 1979.
2. Mohagheghi AA, Moraes R, Patla A E. The effects of distant and on-line visual information on the control of approach phase and step over an obstacle during locomotion. *Experimental Brain Research*, 155, 459-468, 2004.
3. Patla AE, Davies TC, Niechwiej E. Obstacle avoidance during locomotion using haptic information in normally sighted humans. *Experimental Brain Research*, 155:173-185, 2004.
4. Patla AE, Greig M. Anyway you look at it, successful obstacle negotiation needs visually guided on-line foot placement regulation during the approach phase, *Neuroscience Letters* 397:110-114, 2006.
5. Rodrigues, S. T., Forner Cordero, A., Garcia, V. D., Zago, P. F. P., & Ferasoli, H. Influence of visual information on optimal obstacle crossing. *European Conference of the International Federation for Medical and Biological Engineering Proceedings*. Berlin: Springer, 22, 2133-37, 2008.

Table 1 Overall mean (SD) values of blind, blindfolded and vision conditions over the 30 experimental trials: Critical Time, Toe Peak Time, Toe-Obstacle Distance, Heel-Obstacle Distance, Toe Clearance, Step Velocity, Error.

Dependent variable	Blind	Blindfolded	Vision
Critical Time (%)	66.3 (5.4) [a]	72.0 (5.5)	73.1 (5.2)
Heel-Obstacle Distance (cm)	33.6 (11.6)	36.7 (11.7) [a]	29.3 (5.5)
Toe Clearance (cm)	18.7 (7.4)	19.7 (6.2) [a]	14.3 (3.0)
Step Velocity (cm/s)	68.9 (30.7)	70.8 (25.4) [a,]	94.9 (27.4)
Error (units)	0.14 (0.4)	0.21 (0.6) [a]	0.0 (0.0)

[a] Significant effect of Group or Condition.