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Original Article

Influence of obstructions on obstacle-crossing motion during walking

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Abstract. [Purpose] The purpose of this study was to clarify whether the presence of obstructions changes the crossing motion during walking based on the visual perception of obstacles. [Participants and Methods] We included 25 healthy university students as the participants in this study. They were asked to step over obstacles while walking under two conditions i.e., with obstruction and without obstruction. We analyzed the distance between the foot and obstacle (clearance), trajectory of foot pressure movement and distribution as measured by a foot pressure distribution measurement system, and stance phase time. [Results] No significant differences were found between the two conditions for either clearance or foot pressure distribution. In other words, no difference in crossing motion was observed after visual recognition of the obstacle, both in the presence or absence of the obstruction. [Conclusion] The results suggest that no differences exist in the accuracy of recognizing visual information about an obstacle through different mechanisms of selective visual attention.

Key words: Obstacle crossing motion, Visual perception, Obstruction

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INTRODUCTION

The visual world that humans normally perceive contains a vast amount of information. This information is constantly changing due to changes in the external environment and the movement of the individual. Visual information contains many different objects, which comprise features such as color and shape[1)]. When representing the vast amount of information and features from an ever-changing visual world, the human brain has limited processing capacity and cannot process all information at the same time. Humans therefore have a system called “visual attention” that preferentially selects the information to be processed. Several categories of visual attention exist, and different functions of attention are thought to be used to focus on different types of information and thus increase the efficiency of visual information processing[2)].

In addition, visuospatial cognition resulting from visual information gathered in this way is usually closely related to human actions. For example, when walking to cross an obstacle several steps ahead, the external environment around the feet is unconsciously recognized as the obstacle is approached, and information such as the location and height of the obstacle are believed to be acquired from the peripheral vision without requiring direct gazing at the object from a few steps before the obstacle[3–5)]. The individual selectively directs attention to obstacles from among all the visual information obtained while walking, and acts based on the processed information[6)]. If obstructive information is present in the vicinity of an obstacle that distracts the attention of the individual, does this change the information processing of the location, height, and depth of the obstacle? Although obstructive information may reduce the accuracy of recognizing an obstacle information and change subsequent crossing behaviors, the details of the effects of such environmental factors around obstacles in behavior have yet to be clarified. Crossing over obstacles is something that is frequently done in daily life. Visual information is most important

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*Corresponding author. Makoto Sasaki (E-mail: masasaki@hs.akita-u.ac.jp) for this movement, and interference with visual information input is thought to increase the risk of falling. Therefore, it is important to examine the influence of visual disturbance information on obstacle crossing during walking. Our hypothesis is that the presence of obstructions around obstacles adversely affects obstacle-crossing behavior during walking.

The purpose of this study was to clarify whether the presence of obstructions changes the crossing motion during walking, focusing on the condition of visual perception of obstacles.

PARTICIPANTS AND METHODS

Participants in this study were 25 healthy university students (12 males, 13 females) recruited from the public by means of posters posted on a bulletin board. The number of participants needed for adequate power was calculated using G*Power (version 3.1.9.6; Faul F, Kiel, Germany). In Japan, all students over the age of 18 are legally responsible for contracts, so all students were sampled. Inclusion criteria for participants were those who could understand and perform the task, regardless of gender, body type, or exercise habits. Exclusion criteria were: 1) more than two falls in the preceding year; 2) history of visual impairment; or 3) presence of orthopedic or neurological diseases. Participant characteristics (mean ± standard deviation) were: age, 21.7 ± 0.81 years; height, 166.3 ± 9.2 cm; weight, 60.9 ± 11.7 kg; and BMI, 21.9 ± 3.1 kg/m^2. This study was approved by the ethics committee of Akita University Graduate School of Medicine and Faculty of Medicine (approval no. 2855). The purpose of the study was explained to all participants both orally and in writing, along with the entirely voluntary nature of participation and withdrawal.

In the research design, we first prepared a walkway in a room with ample space, and placed obstacles that could be easily crossed far from the walkway. Participants were made to wear a measurement sheet for foot pressure analysis and performed a task to cross an obstacle. We measured the distance between the foot and the obstacle as well as the foot load parameters of the crossing leading leg when the participant crossed the obstacle. Measurement results were compared with and without obstructions.

A 90-cm-wide straight walking path was outlined with black vinyl tape, and a black obstacle (60 cm wide, 15 cm deep, and 10 cm high) was placed 5 steps ahead. Distance between the obstacle and the foot, foot pressure trajectory, foot pressure distribution, and stance time were measured when a fabric obstruction (90 cm wide, 160 cm deep) with black spots on a white background was placed around the obstacle (a condition with obstruction; Fig. 1) and when the plain white fabric of the same quality was placed around the obstacle (condition without obstruction). Foot pressure distribution and stance phase time were measured. Participants were asked to visually perceive an obstacle at a distance of 5 steps for 1–2 s, then step over the obstacle by looking ahead without gazing at the obstacle. The order of presentation for the two conditions was randomized, and a sufficient rest period was provided between conditions.

The distance between the obstacle and the foot was measured as the shortest vertical distance between the anterior upper edge of the obstacle and the toe (toe clearance) and between the posterior edge of the obstacle and the heel (heel clearance).

In the foot pressure distribution measurement system, measurement items were foot pressure movement trajectory, foot pressure distribution, and stance phase time, and the first step after crossing the obstacle was analyzed. Toe clearance and heel clearance were captured using a high-speed digital camera (EX-ZR1100; CASIO, Tokyo, Japan) at a sampling frequency of 240 Hz and analyzed using Dartfish software (Dartfish, Tokyo, Japan). Foot pressure trajectory, foot pressure distribution, and stance phase time were measured using F-scan (NITTA, Osaka, Japan). Foot pressure trajectory is expressed as the distance traveled by the load center along the longitudinal axis (trajectory length) divided by the foot length and multiplied by 100 (%). Lateral axis movement is expressed as the load center movement index, as the ratio (%) of the distance traveled by the load center in the lateral direction to the foot width. Foot pressure is expressed as the load applied to the heel, midfoot, and metatarsus divided by body weight.

Fig. 1. Walking path and obstacle with obstructions.

The Shapiro–Wilk test was used for statistical processing. If the normality of the distribution was confirmed, each parameter was compared between the two conditions using a paired t-test. If normality was not confirmed, the Wilcoxon signed rank-sum test was used. SPSS version 28 (Japan IBM, Tokyo, Japan) was used as the statistical analysis software, with the significance level set at 5%.

RESULTS

Inter-condition comparisons of clearance are shown in Table 1. No significant differences were found between conditions for either toe clearance or heel clearance.

Table 2 shows an inter-condition comparison of items taken by the foot pressure distribution measurement system. Again, no significant differences were seen between conditions in any of the measurements of foot pressure trajectory, foot pressure distribution, or stance phase time.

DISCUSSION

At the outset, we explained some of the function of visual attention. The visual system is known to perceive input visual information by dividing it into object and background categories. In other words, objects are separated from the background of a visual scene and various information processing is then performed7).

Several types of attention have been defined. One such type is spatial attention, which functions on space and location7, 8) and can be further divided into overt and covert attention7). Spatial attention includes explicit attention, which selects information by shifting the gazing position with eye movements, and implicit attention, which directs attention independently of the gazing position7). In this study, the participant was instructed not to gaze at obstacles from the beginning of walking, so information processing of obstacles by the function of this implicit attention was thought to have occurred during walking.

In addition, top-down and bottom-up mechanisms have been identified from a series of studies as mechanisms of controlling attention1, 9–12). The top-down mechanism is active attention9), in which the specific weight of attention to certain stimuli can be increased when cues are given in advance about their locations and characteristics13). For example, this mechanism is used when looking for a red book on a bookshelf or when looking for one's car in a parking lot. Filtering, one of the functions of the top-down mechanism, has been reported to involve the elimination of unnecessary information and prioritization of objects of high behavioral importance for information processing13, 14). For example, when we read a text, filtering allows us to eliminate textual information other than the one sentence we are reading. However, although the top-down mechanism is essential for visual search and adaptive behaviors in the environment, the individual does not always have prior information about the object to which attention is to be directed. The bottom-up mechanism, as passive attention, thus functions for stimuli with salient features or that appear suddenly9). The red color of the rising sun, the first star in the night sky, or a child running out into the street are examples of stimulus, and the bottom-up mechanism unconsciously attracts attention.

In the with-obstruction condition in the present study, we reduced the prominence of the obstacle in the walking path by making the obstacle and the obstruction identical colors, thus interfering with the aforementioned separation of the obstacle from the background and the bottom-up mechanism.

Table 1. Comparison of clearance between conditions

	With obstructions	Without obstructions
Toe clearance (cm)	7.80 ± 0.24	8.24 ± 2.13
Heel clearance (cm)	5.96 ± 2.70	6.04 ± 2.95

Values represent mean ± standard deviation.
Wilcoxon signed rank-sum test.

Table 2. Comparison of items from foot pressure distribution measurement system between conditions

	With obstructions	Without obstructions
Trajectory length/foot length (%)[b]	71.1 ± 10.2	72.7 ± 67.0
Center of load range of motion index (%)[b]	24.4 ± 11.1	27.0 ± 13.5
Heel-maximum load-to-weight ratio[b]	55.3 ± 19.2	56.1 ± 16.2
Midfoot maximum load-to-weight ratio[a]	11.8 ± 14.7	11.4 ± 16.0
Metatarsal maximum load-to-weight ratio[b]	55.1 ± 20.3	53.3 ± 19.0
Stance phase time (s)[a]	0.81 ± 0.11	0.80 ± 0.10

Values represent mean ± standard deviation.
[a]Paired-sample t-test; [b]Wilcoxon signed rank-sum test.

We hypothesized that such obstruction of attentional characteristics would interfere with the processing of information such as the height, depth, and location of the obstacle, which would negatively affect the crossing motion after a few steps of walking.

We considered the influence of the top-down mechanism, as a mechanism of visual attention control similar to the bottom-up mechanism. With the top-down mechanism, prior knowledge of the features and spatial location of the stimulus to be selected enables selective attention to that stimulus. Under the with-obstruction condition, the prominence of the obstacle (a bottom-up mechanism) is reduced by the obstructing information.

The participant therefore encountered a "hard-to-see" obstacle and had to process the information about this hard-to-see obstacle through implicit attention, since the participant did not directly gaze at the obstacle while walking. This obstructive information could conceivably cause the participant to direct their conscious attention to the obstacle independent of eye movements. This means that the participant directs active attention (top-down mechanism) to the obstacle of the highest behavioral importance and preferentially processed information for that obstacle alone. This preferential processing for obstacles (i.e., the elimination of obstructive information around obstacles) is performed by the filtering function of the top-down mechanism.

In the without-obstruction condition, on the other hand, the contrast (prominence) of the black obstacle against the white walking path was so strong that the participant would naturally process information about the obstacle through passive attention. This passive attention based on stimulus salience corresponds to bottom-up attention.

Based on the above considerations, we believe that the same obstacle information was processed through different mechanisms under the without-obstruction and with-obstruction conditions in the present study. The fact that no effect was seen on subsequent behavior suggests a lack of difference in the accuracy of obstacle information obtained via the different mechanisms.

Although the obstructions used in the present study were flat objects of the same color as the obstacle, addition of more salient stimuli (such as through the use of projection mapping) or the presence of obstructions as 3-dimensional objects similar to the obstacle have been reported to result in competition between top-down and bottom-up mechanisms[2, 10, 15], and the crossing behavior itself was not affected. The competition between top-down and bottom-up mechanisms continues to be debated, and some researchers have recently proposed that trying to explain the control mechanisms of visual attention via this dichotomy is not appropriate[9]. Further studies are needed regarding competing control mechanisms of selective attention in visual perception and their influence on movement.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

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