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The Effects of Visual Feedback on Treadmill Walking Speed

Ruthie Muqatach and Seung-Jae Kim*

Department of Biomedical Engineering, California Baptist University, Riverside, CA 92504, USA

***Corresponding author:** Seung-Jae Kim, The Gordon and Jill Bourns College of Engineering, California Baptist University, 8432 Magnolia Avenue, Riverside, CA 92504, USA, Tel: 9515528635; Fax: 9513434782; E-mail: sjkim@calbaptist.edu

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Abstract

Gait rehabilitation often utilizes treadmill training, and providing visual feedback on subjects' movements can improve the rehabilitation outcomes. We have previously shown that an imposed distortion of visual feedback on subjects' step lengths entails unintentional changes in gait symmetry. In light of the potential effect of distorting visual feedback, we decided to test if we could change the walking speed of subjects using distorted visual feedback display. This is because gait training outcomes are correlated with increasing walking speed. Healthy subjects participated in the treadmill walking trials. During the trials, a motion capturing system tracked the position of the subjects' foot and hip, and a computer displayed the current step length of each leg on a screen as vertical bars. Horizontal bars then scroll down the screen, and when the top of the step length bar lands on the horizontal bar, a sound as well as a temporary change in color of the horizontal bar is produced. In each trial, the subjects walked on a treadmill while looking at the computer screen. Then, we implicitly distorted the scroll speed or the distance between the horizontal bars in an attempt to get the subjects to change their walking speeds by spontaneously stepping on the horizontal bars in the computer screen. A computer program detected any sign of change in the walking speed and automatically adjusted the treadmill speed. While further studies need to be done with a larger sample size, we found that the subjects showed a tendency to increase their speed in the intended manner. The results of this study may herald a promising approach for gait rehabilitation because the visual feedback distortion can be used to encourage the subjects' movements beyond their voluntary efforts.

Keywords: Visual feedback; Gait rehabilitation; Treadmill training; Walking speed

Introduction

Better functional outcomes from therapy are highly correlated with the intensity of training [5]. Thus, patients would benefit from increasing their speed during treadmill training [6]. Typical training methods involve telling the patients to walk faster, which is tedious for both the trainer and the patients. The limitation of such methods is that they have to rely on an explicit manner in which the patients have to consciously and voluntarily change their walking motion. Training in such an explicit manner may involve an adaptation process that is faster but transiently stored [7,8]. We have previously presented a rehabilitative paradigm called visual feedback distortion that can drive implicit (or unconscious) changes in gait symmetry [2-4]. It is possible that training in an implicit manner results in an improved outcome of gait training over conscious corrections in movement [9-11]. Therefore, the objective of this study was to see if visual display distortion could spontaneously change a person's walking speed on a treadmill. To perform this, we have developed a novel method of using visual feedback display where, in addition to the vertical bars representing step length (Figure 1A), we included horizontal bars that scroll down the screen. This horizontal bar would change color and make a sound when a foot lands on the inside of the bar (Figure 1B). For visual distortion, we manipulated the visual feedback display by increasing the scroll speed or the distance between the bars (Δd) implicitly (subjects were unaware of the changes) in hopes that the subjects would modulate their gait speed during treadmill walking by spontaneously attempting to step on the bars in the computer screen. The results from our pilot experiments demonstrated a spontaneous change of speed in response to the visual feedback manipulation, thereby indicating the potential effects of visual feedback distortion on modulating subjects' walking speed during treadmill training.

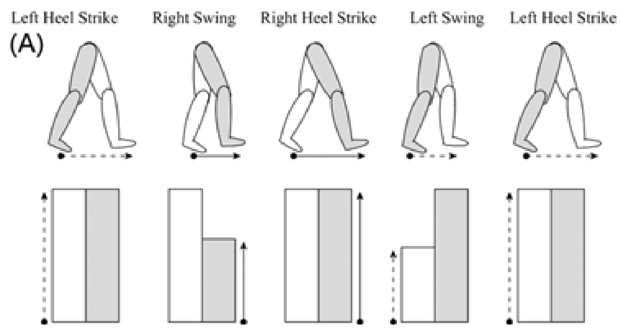

Figure 1A: For visual feedback display, the ranges of the right and left step length were mapped to the visual feedback vertical bars. For example, during the swing phase of a leg, the corresponding bar increases in real time proportional to the step length and stops when a heel strike occurs for that leg.

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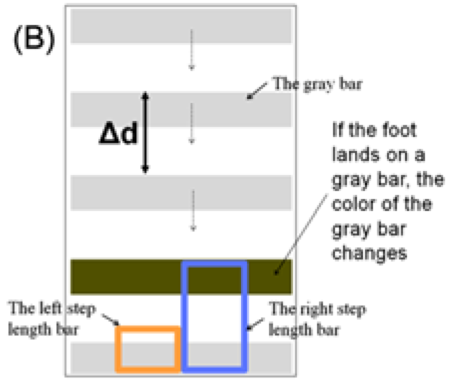

Figure 1B: In addition to the vertical bars, the gray horizontal bars move down when walking treadmill and the bar is darkened if the foot lands on it.

Materials and Methods

Healthy male and female subjects ages 19 to 41 walked on a treadmill for a 6-min period at their preferred speed under two conditions: (1) one condition would increase the scroll speed of the horizontal bars (termed "speed-up trial"), and (2) the other condition would increase the distance between the horizontal bars (termed "distance-up trial"). A motion sensor (Optotrak, Northern Digital) was used to measure the position of each subject's feet and hip. Throughout each trial, we showed the subjects their step lengths in real time, as represented by a vertical bar for each leg (Figure 1). As the subject takes a step, the corresponding bar increases in height until it reaches its maximum value at a heel strike. After a short time, gray horizontal bars appear and begin scrolling down the screen. The initial distance apart the horizontal bars was determined based on the subjects' walking pattern recorded in the first 90 seconds of each trial, so that if the subject continues walking the same way, the tops of the vertical bar would 'hit' the horizontal bar. When the subjects stepped on the bar, the customized LabVIEW program made a sound and the bar temporarily became a darker shade of gray. This was designed to get the subjects motivated to step on the bars to change their speed. However, we did not instruct the subjects to step on the bars; they were instructed to walk comfortably over the course of the trial. Soon after the horizontal bars appeared (at 90 seconds of trial), our treadmill speed-changing algorithm was turned on and automatically adjusted the treadmill speed according to the subjects' intention of changing their walking speed. The algorithm tracked the subject's hip position with respect to the treadmill to determine the intention for changing speed. During the speed up trials, the scroll speed of the horizontal bars increased by 2% of the initial speed up to 106% every minute. In the distance-up trials, the distance between the horizontal bars increased by 0.5% up to 102% every minute (Figure 2). The mean walking speed values over different distortion (scaling factor) levels (with 30-second period) were calculated per subject, averaged across all of the subjects, and were used to test the changes in walking speed induced by the implicit visual distortion for the analysis of (Figure 3). A two sample t-test at a 90% confidence level was used to examine whether the walking speed at different time periods would be different from the initial (base) period.

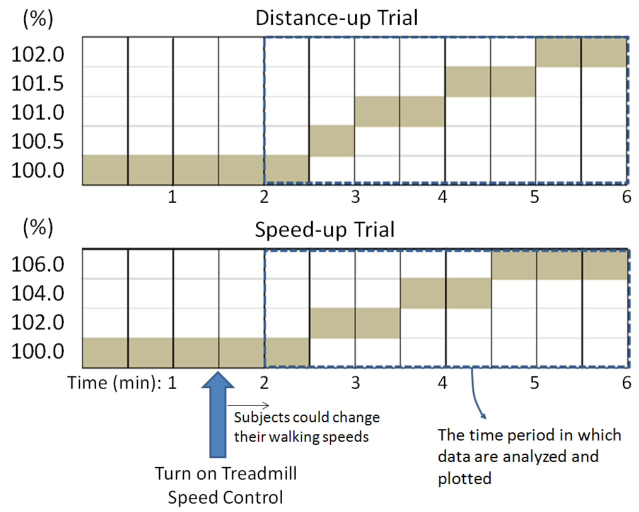

Figure 2: Applied distortion profile for the distance-up and speed-up conditions. The changes are represented by % of the initial; the initial speed and distance between the bars is defined as 100%.

Results

Figure 3 shows the average subject speed as a function of time. Every subject started out at a different preferred speed, so we showed the data as a percentage of the speed that each subject was going before we changed anything about the horizontal bars. For this reason, the speed for the first 30 seconds is 100 because that is the base that we used for the rest of our data. We also showed the distortion scaling factor (for change of the horizontal bar scroll speed and the bar distance) as a percentage (100% represents how the distance between the horizontal bars started out). As shown in Figure 3A, the distance increase showed an increase in speed, but with a large standard deviation. Figure 3B shows that the walking speed increased as the speed of the horizontal bars got faster.

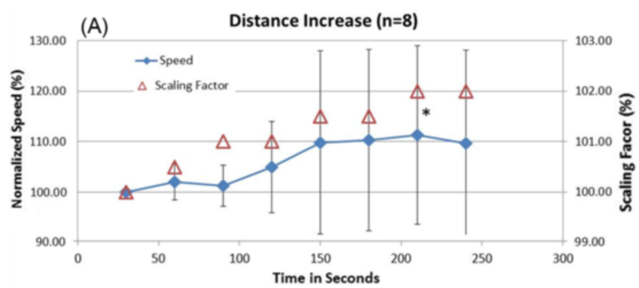

Figure 3A: Changes in the mean walking speed ± one standard deviation, averaged across 8 subjects during distance-up condition. The horizontal axis show time, the left vertical axis shows the normalized speed (%) and the right vertical axis shows the distortion level (%) applied during trials. The asterisks (*) donates the time where the modulated speeds were shown to be significantly different from the initial (base) period (p<0.1, using t-test).

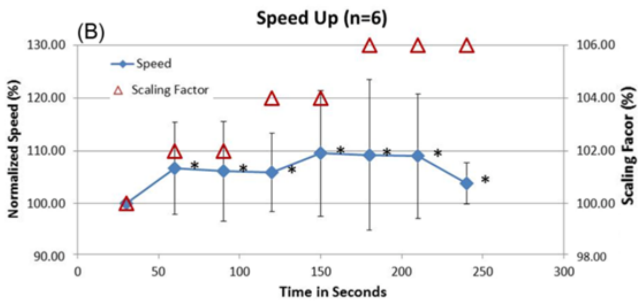

Figure 3B: Changes in the mean walking speed ± one standard deviation, averaged across 6 subjects during speed-up condition.

Discussion and Conclusion

Our pilot experiment shows that subjects spontaneously modulated their walking speed as the distance between the horizontal bars or the scroll speed of the horizontal bars changed even with the instruction of walking comfortably during the trial. The distance-up trial showed an increasing trend of walking speed in response to increased distance between the horizontal bars (Figure 3A), even though the amount of increase was not statistically significant due to the large variations. In the speed-up trials, the increasing trend of speed in response to increased scroll speed of the bars was more apparent (Figure 3B). Our study showed similar results on changes of walking speed between two different trials (changing the scroll speed of the horizontal bars and changing the distance between the bars). More tests with a larger sample are needed, but we expect that changing the scroll speed of bars will have more impact on walking speed modulation than changing the distance between bars. This is probably because people may adapt to faster gait steps more easily than longer gait steps. Most subjects did not seem to have attempted to step on the bars at every heel strike, and they remained unaware of the changes of their walking speed. However, subjects modulated their step length to some degree in response to the changes of the scroll speed of the bars or the changes of the distance between the horizontal bars, thereby leading to a change in walking speed. These results indicate that distortion of the visual display, as used in our experiment, has a potential to get subjects to spontaneously modulate walking speed during a treadmill walking. We hope that such a novel way of distorting visual information integrated into gait training could benefit individuals with gait deficiency by providing more efficient means to train.

One of the limitations of our study is the speed-changing algorithm used to change the speed of the treadmill, and we are still working to figure out a more intuitive way to change the speed of the treadmill and more incentive to step on the horizontal bars. Another limitation is the small sample size. Despite such limitations, our results have shown that the distortion of the visual information, as used in our experiment, can have some impact on changing subjects' gait speed during treadmill training. Further experiments, however, need to be pursued to make more conclusive evidence.

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