Effects of visual feedback distortion on gait adaptation

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ABSTRACT

Gait rehabilitation following neurological disorders often utilizes the correction of stepping movements, which entails adaptive changes through practice that eventually leads to permanent gait adaptation. To enable gait training to be more effective, providing visual feedback on subjects’ movements during rehabilitation training can help engage subjects’ participation beyond their specified task. Our previous experiments [1-2], which used the implicit and explicit distortion of visual feedback, showed the effect of visual feedback distortion on changes in gait symmetry and suggested that such an effect involves non-volitional resources. We have further explored the process of gait adaptation induced from visual feedback distortion with the following question: How would the changes in gait symmetry induced by implicit visual feedback distortion, versus conscious control of gait symmetry, modify adaptation? Our results showed that subjects trained with visual feedback distortion retained aftereffects longer than with conscious correction of stepping. This study suggests that a therapeutic program employing visual feedback distortion paradigm could provide an effective way to help patients correct gait patterns, thereby improving the outcome of rehabilitation.

Keywords

Gait rehabilitation, Visual feedback distortion, Modulation of locomotion, Step length symmetry, Gait adaptation.

1. INTRODUCTION

Gait rehabilitation following neurological disorders often utilizes correction of stepping movements. Such rehabilitation approaches require adaptive changes through practice that eventually leads to permanent motor adaptation of human locomotion [3]. Therefore, gait rehabilitation needs to emphasize techniques that drive recalibrations of motor commands for locomotion rather than just evoke a reactive type of adjustment during training [4]. Providing visual feedback on subject’s movements during gait rehabilitation may enhance the process of such gait adaptation by engaging subjects’ participation beyond their voluntary effort [5-6]. We have previously demonstrated that an explicit and also an implicit distortion of visual feedback regarding step length entail unintentional modulations in gait spatial pattern to some degree [1-2]. In this paradigm, the visual feedback of step length symmetry was displayed on a computer screen and was also distorted so that subjects perceived their step length as being asymmetric during treadmill walking. We found that a gradual distortion of visual feedback systematically modulated gait step length away from symmetry. Since walking is normally an implicit process, it is possible that gait adaptation is driven using more implicit and automatic processes than voluntary control of movement. Thus, the aim of this study was to explore the process of gait adaptation resulted from visual feedback distortion. Here we tested whether the changes in gait pattern induced by implicit visual feedback distortion, versus conscious correction of walking, modifies adaptation. Two different conditions were tested: 1) implicit visual distortion condition was given no specific instruction with on-line visual distortion feedback, and 2) conscious correction condition was given voluntary control of gait symmetry with on-line visual-guided feedback. In treadmill walking trials, the visual feedback display was removed during adaptation while subjects continued walking. Then, retention of aftereffects (de-adaptation) was assessed in all subjects. Our study showed that subjects trained with visual feedback distortion retained aftereffects longer than the conscious correction group, suggesting a potential effect of visual feedback distortion on recalibrations of motor commands for locomotion. In the context of gait rehabilitation, a therapeutic program involving visual feedback distortion, in the context of gait rehabilitation can provide an effective way to help subjects correct gait patterns, thereby improving the outcome of rehabilitation.

2. MATERIALS & METHODS

Seven healthy volunteers participated in this study. All subjects gave informed written consent before participating and were familiar with walking on a treadmill. Subjects were first habituated to walk on the treadmill and determined a comfortable walking speed (range 1.8–2.2 mile/hour) after 10 to 15 minutes of habituation. Subjects continued to walk comfortably on the treadmill. The on-line visual feedback showed step length information represented by bar graphs provided via a computer screen in front of a treadmill (Fig. 1). A computer screen (24” LCD monitor) was placed in front of the treadmill to display visual feedback information (the distance between subjects and the screen was about 4 feet).

The step length is defined as the distance between each foot when heel-strike occurs for one leg. The visual feedback consisted of bar heights representing the instantaneous distance between each foot, so that the bars were gradually increased during the swing phase (two feet were getting further apart). The maximum height of the bar occurred when heel strike occurred on the corresponding side, and the maximally displayed bar trace stayed on until the following swing phase began. When distorting the visual feedback, we increased the range of the bar for only one side (the right side). The distortion increments used in this study was 2%. For example, 2% of distortion changed the scaling factor
between the actual right step length and the displaying bar height from 100% to 102%. In this way, subjects visually perceive that their right step length is 2% longer than the actual length, and this percentage of distortion varied during the trials.

Figure 1. Visual feedback display. The range of the right and left step length was mapped to the visual feedback bars, shown in the bottom row. For example, during the swing phase of the leg, the corresponding bar increases in real time proportional to the step length and stops when heel-strike occurs for that leg. The range of step length mapped to the visual bar was then gradually distorted.

Actual step length was measured using an optometric tracking system (OPTOTRAK system, Northern Digital Inc., Canada). Two infrared markers were attached on the heel sides of the subjects’ shoes. The markers emit the infrared light, which is seen by a 3-D camera to locate their positions. The position data of the markers were retrieved to a PC in real time using a program constructed using LabVIEW to graphically represent the step length measurements.

The experiment was divided into two sessions for testing two different conditions (implicit visual feedback distortion and conscious correction condition) with the same subject. The first session began with 14 minutes of visual distortion-influenced walking and ended with 6 minute of walking without visual feedback (a total of 20-minutes trial). During the first 14 minutes of walking, the distortion was gradually increased by increments of 2% up to 114%. Each distortion level lasted for 30 seconds. The second session took place a week after the first. For the second condition, the targeted asymmetries during the first 14 minute periods were set to the same asymmetric values induced from the condition of implicit visual feedback distortion. Thus, subjects consciously generated asymmetric gait by attempting to match the maximum height of the right and left bars displayed by the computer screen during the trial. During the first 14 minutes walking (visually-guided) was also followed by 6 minutes with no visual feedback. Retention of aftereffects was assessed for both conditions.

3. RESULTS

Figure 2 shows an example of adaptation and de-adaptation (aftereffect) for step symmetry for two different conditions obtained from a single subject. The horizontal axis shows time; the vertical axis shows step length ratio between the actual left and right step lengths. (Top) The intermittent horizontal lines indicate distortion increments applied during those time periods. (Bottom) Mean difference of step symmetry between two different conditions. The mean values of conscious correction condition were subtracted from those of implicit visual distortion condition. This plot shows that the effect of adaptation remained longer during the period of de-adaptation in response to visual feedback distortion trial than to conscious correction of stepping.

Figure 3 shows the mean difference of step symmetry between the implicit visual feedback condition and conscious correction condition for all seven subjects. The bars represent the mean difference per each different distortion increment and also during de-adapation period (no-visual feedback period). An asterisk (*) indicates that they were statistically different from the base line (the initial symmetric gait).
As shown in Figure 3, it was observed that there were some variations in the induced gait asymmetry between two conditions during the first 14-minutes adaptation period. This might be due to the fact that although subjects tried to generate the same amount of asymmetric gait as induced from the implicit visual feedback trial, it might be difficult to control their gait stepping perfectly. However, such variations were small (less than 2%) and they became significantly larger during the de-adaptation period suggesting that the de-adaptation process was slower during the implicit visual disotrrion trial than during the conscious correction of walking trial.

4. CONCLUSIONS

The present study investigated the effect of implicit visual feedback distortion, versus conscious correction of gait symmetry, on influencing gait adaptation of step length symmetry. The visual information used in this study was simple bar graphics, not altering visual space nor evoking illusions. The results of this study showed that subjects spontaneously modulated their gait symmetric pattern away from symmetry according to the distortion of visual feedback. The effect of visual feedback distortion changes in step symmetry appears to involve unconscious or implicit motor functions. In addition, this study showed that subjects trained with visual feedback distortion retained aftereffects longer than with conscious correction of gait symmetry. These results suggest that the effect of visual feedback during gait is unnoticed and spontaneous and also that a paradigm of using such visual feedback distortion may be potentially useful as a supplemental therapeutic intervention for gait rehabilitation, thereby improving the outcome of rehabilitation.

5. ACKNOWLEDGMENTS

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6. REFERENCES