

The Effects of Integrated Visual and Auditory Stimulus Speed on Gait of Individuals with Stroke

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Abstract. [Purpose] This study investigated the effects of integrated visual and auditory stimulus on the spatio-temporal gait parameters of individuals with hemiparetic stroke. Twelve patients with post-stroke hemiparesis from the Department of Rehabilitation Medicine of B Hospital in Seoul, Korea were enrolled in this study. [Methods] We carried out gait analysis of the participants under 3 different conditions of visual and auditory stimulus speed. Gait velocity, cadence, stride length, and step length were measured while the patients walked on the GaitRite system. [Results] Slow integrated auditory and visual stimulus (50%) significantly decreased gait velocity, cadence, stride length, and step length of both the paretic and non-paretic lower limbs as compared to the other conditions. Fast integrated visual and auditory stimulus (150%) significantly increased gait velocity, cadence, stride length, step length, and single support time of both lower limbs as compared to the other conditions. [Conclusion] Our results show that the speed of integrated visual and auditory stimulus modulates the spatiotemporal parameters of gait of chronic stroke patients. The information presented here is important for investigators who use integrated visual and auditory stimulus for the rehabilitation of individuals with hemiparetic stroke.

Key words: Optic flow, Rhythmic auditory stimulation, Gait parameter

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INTRODUCTION

Stroke patients suffer central nervous system injury, which results in muscle weakness, abnormal muscle tone, abnormal balance, and abnormal postural control, and they also experience difficulty with motor control¹⁾. Because of this, post-stroke gait is characterized by slow gait cycle and velocity, a time imbalance between the lower extremity of the affected side and that of the unaffected side, a shorter stance phase on the affected side, and a relatively long swing phase^{2, 3)}.

Recently, auditory stimulation⁴⁻⁶⁾ and visual stimulation^{4, 7, 8)} have been used to improve the gait ability of stroke patients. Rhythmic auditory stimulation (RAS) is a type of neurologic music therapy that uses rhythmic sensory stimuli. RAS influences the motor control system of the brain and gait motion through timing cues, eventually changing the temporal gait parameters⁹⁾. In patients with neuromuscular disorders who have difficulty with activities of daily living due to decreased sensory and motor ability, and who have asymmetric feedback of sensory-motor control, brain activity increases in response to RAS, the movement of the paralyzed part becomes more normal, and the brain

activity pattern becomes smoother, as assessed by functional magnetic resonance imaging and positron emission tomography^{10, 11)}.

Optic flow is the typical pattern of the eyes' visual motion following human movement in the environment. Because optic flow reveals the direction and speed of expected self-motion, it is a source of visual information that can be used to control the direction and speed of walking. When the velocity of optic flow is controlled to create a mismatch between proprioceptive information received from the lower extremity, gait velocity adapts to decrease the incongruity⁷⁾. Lamontegne et al. reported that when changes were induced by visual stimulation, using the velocity of optic flow, stroke patients changed their gait parameters⁷⁾.

Changes in the velocity of auditory and visual stimulation affect the gait parameters of stroke patients. However, no studies have yet examined simultaneous auditory stimulation and visual stimulation. Therefore, this study examined the effect of changes in the rapidity of combined auditory and visual stimuli on the gait parameters of stroke patients in order to utilize the results as basic information for their rehabilitation.

SUBJECTS AND METHODS

The subjects of this study were 12 post-stroke inpatients of B Rehabilitation Hospital, Seoul, Korea. They were randomly chosen using sealed envelopes before the start of the intervention from among those who understood the study and showed a clear will to participate in it. We chose those hemiparetic patients who had experienced a stroke at least 6 months earlier and were able to walk more than 10 m independently; who did not have visual impairment, hearing problems, and surgical and mental disorders affecting walking; whose scores on the Mini-Mental State Examination were more than 24; and whose Brunnstrom stages were more than 4¹⁾.

All subjects on the GAITRite system at their usual speed before the experiment, and the speeds of the visual and auditory stimuli were divided into 3 levels: 50%, 100%, 150% the walking speed of each patient. For the experiment, subjects walked on the GAITRite while looking at a screen and listening to auditory signals produced by a metronome, and their gait parameters were measured. Before the experiment, each patient was given 5 min to adapt to the visual and auditory stimuli 3 different stimulation speeds were performed randomly, and each was performed 3 times. For the safety of the patients, each had an assistant, and the use of canes or quadripod canes was allowed.

To collect quantitative data on the patients' gait characteristics, the temporal and spatial walking abilities of patients were measured using the GAITRite system (CIR Systems, Inc., USA). GAITRite is a walking board that is 5-m long, 61-cm wide, and 0.6-cm high. Temporal and spatial variables are measured by 16,128 sensors, each of 1-cm diameter, that are embedded every 1.27 cm along the board. Temporal and spatial variable data were analyzed using the GAITRite Gold, Version 3.2b software, (CIR Systems, Inc., USA). In the test, each patient stood in front of the walking board and, when the tester gave a signal, the patient walked onto and along the walking board, at his or her most comfortable speed. Computerized analysis determines temporal gait characteristics such as velocity and cadence, and spatial gait characteristics such as step length and stride length. The measurement reliability of this test is $r = 0.90^{12, 13)}$.

To exclude the acceleration and deceleration stages of walking from our measurements, the patients began walking 2 m before the start of the walking board and continued 2 m past the end of the walking board. Walking aids like canes were allowed, depending on patients' needs. Each measurement was made 3 times, and 3 min of break time was given to patients between measurements to minimize the effects of muscular fatigue. SPSS 12.0 was used for the statistical analysis. To compare the gait parameters among the audio-visual stimulus speeds, repeated ANOVA was used, and significance was accepted for values of $p < 0.05$.

RESULTS

Baseline characteristics can be seen in Table 1. The changes in spatiotemporal parameters of gait during the modulation of integrated visual and auditory speed are

presented in Table 2. First, slow integrated auditory and visual speeds (50%) significantly decreased gait velocity, cadence, stride length, and step length in both paretic and non-paretic lower limbs as compared to the other conditions ($p < 0.05$). Second, fast integrated visual and auditory speeds (150%) significantly increased gait velocity, cadence, stride length, step length, and single support time in both lower limbs as compared to the other conditions ($p < 0.05$).

DISCUSSION

In this study, we conducted gait analysis of stroke patients provided with visual and auditory stimuli and compared the gait characteristics of the different stimulus speeds. In a study analyzing the gait parameters of Parkinson disease patients provided visual and auditory stimulation, Arias and Cudeiro reported that lower gait velocity, cadence, and step amplitude and higher coefficient of variation in stride time and step amplitude were shown at the lower speed of stimulation¹⁴⁾. In this study, we found that gait velocity, step length, and stride length increased significantly when visual and auditory stimulation were provided at 150% of patients' normal walking speed compared to stimulation at 50% of their normal walking speed, which is similar to the findings of the abovementioned study.

The speed of visual information decreases the incongruity of proprioceptive information from the lower extremity through the perception of a visual cueing speed that is faster or slower than the gait velocity of test subject inducing a change in the gait velocity of the test subject⁷⁾. As optic flow provides information on the expected movement velocity and direction of movement, it becomes a source of visual information that can control the velocity and direction of gait ultimately affecting a person's gait velocity¹⁵⁾. In a study that compared the gait velocity of stroke patients with continuous optic flow and discontinuous optic flow, Lamontagne et al. showed that a bigger difference was shown in gait velocity at 0.25-fold to twofold discontinuous optic flow, and that faster gait velocity was shown at slow optic flow than at fast optic flow⁷⁾. In addition, virtual reality training equipment can be bought relatively cheaply, is easily operated, fun for patients, and motivates them¹⁶⁾. Jaffe et al. reported that virtual reality training for chronic stroke patients more than 6 months after onset of stroke using a head-mounted device resulted in significantly increased gait velocity and stride length in the virtual reality training group compared to the control group that did not practice virtual reality training¹⁷⁾.

Auditory stimulation arouses the motor neurons of the spinal cord through auditory and motor connections at the brain stem and spinal cord level¹⁸⁾. Thus, auditory information provides stimulation that bypasses the damaged function, leading to good muscle performance or timing control, and sends a motor timing control signal, that is received by the compensatory network of brain, and has a useful effect on the neurological aspects and processed for movement in the brain¹⁹⁾. Roerdink et al. in a cross-sectional study of gait training provided auditory stimuli of 90%, 100%, and 110% normal walking speed to 10 stroke patients and 9 elderly adults. They observed greater improvement

Table 1. General characteristics of the subjects

	Gender (male/female)	Age (years)	Height (cm)	Weight (kg)	Post-stroke duration (months)	MMSE (score)
Subjects (n=12)	7 / 5	52.58 ± 12.42	165.35 ± 11.23	65.74 ± 13.65	15.5 ± 8.5	7.4 ± 2.2

Note. All variables are mean ± standard deviation (SD). MMSE, Mini Mental State Examination.

Table 2. Comparison of gait parameters among the integrated visual and auditory stimulus speeds

		50% (M ± SD)	100% (M ± SD)	150% (M ± SD)
Velocity ^{abc} (cm/sec)		34.97 ± 14.78	46.84 ± 22.05	59.35 ± 25.76
Cadence ^{abc} (step/min)		64.23 ± 12.66	76.74 ± 14.20	87.80 ± 11.32
Stride Length (cm)	Affected side ^{abc}	64.39 ± 15.38	72.64 ± 20.42	80.42 ± 21.92
	Non-affected side ^{abc}	64.39 ± 16.05	72.35 ± 20.32	80.10 ± 21.15
Step Length (cm)	Affected side ^{abc}	32.97 ± 9.10	37.41 ± 10.68	41.32 ± 11.10
	Non-affected side ^{abc}	31.71 ± 6.90	35.49 ± 10.30	39.16 ± 11.50

Note. All variables are mean ± standard deviation. ^aStatistically significant difference between 50% and 100% ($p < 0.05$). ^bStatistically significant difference between 50% and 150% ($p < 0.05$). ^cStatistically significant difference between 100% and 150% ($p < 0.05$).

of stride length and step time symmetries, and coordination ability in the experimental group than the control group²⁰).

In conclusion, when audio-visual stimulation is provided, a mismatch occurs between proprioceptive information from the lower extremities of stroke patients and visual signals, and gait velocity adapts to decrease the incongruity. At the same time, through auditory feedback, lower extremity movement can quickly adjust to the desired gait velocity. In addition, these exercises enable self-modification of gait parameters through continuous visual and auditory information. One limitation of this study was that the effects of visual stimulation and auditory stimulation could not be compared with each other because we did not divide our control group into a visual stimulation group and an auditory stimulation group. Further research will be needed to determine the separate effects of visual and auditory stimulation on stroke patients.

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