



ORIGINAL ARTICLE

Tactile Perception for Stroke Induce Changes in Electroencephalography



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KEYWORDS

electroencephalography;
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Summary *Objective/Background:* Tactile perception is a basic way to obtain and evaluate information about an object. The purpose of this study was to examine the effects of tactile perception on brain activation using two different tactile explorations, passive and active touches, in individuals with chronic hemiparetic stroke.

Methods: Twenty patients who were diagnosed with stroke (8 right brain damaged, 12 left brain damaged) participated in this study. The tactile perception was conducted using passive and active explorations in a sitting position. To determine the neurological changes in the brain, this study measured the brain waves of the participants using electroencephalography (EEG).

Results: The relative power of the sensory motor rhythm on the right prefrontal lobe and right parietal lobe was significantly greater during the active tactile exploration compared to the relative power during the passive exploration in the left damaged hemisphere. Most of the measured brain areas showed nonsignificantly higher relative power of the sensory motor rhythm during the active tactile exploration, regardless of which hemisphere was damaged.

Conclusion: The results of this study provided a neurophysiological evidence on tactile perception in individuals with chronic stroke. Occupational therapists should consider an active tactile exploration as a useful modality on occupational performance in rehabilitation training. Copyright © 2016, Hong Kong Occupational Therapy Association. Published by Elsevier (Singapore) Pte Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

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Introduction

Stroke is due to a cerebral vascular accident that can induce motor and sensory dysfunctions in individuals (O'Sullivan, Schmitz, & Fulk, 2014). Major impairments following a stroke event include muscle weakness, sensory dysfunction, spasticity, cognitive dysfunction, visual spatial dysfunction, and reduced survival. The individuals who survive a stroke often have perceptual impairments and motor dysfunction, which make their participation in rehabilitation difficult (Go et al., 2014). Specifically, 50–85% of patients with poststroke sensorimotor hemiparesis encounter impaired tactile processing and proprioception (Van de Winckel et al., 2012). Tactile perception generally occurs when touching and grasping an object, and is a basic way to obtain and evaluate information about an object (Juravle, Deubel, & Spence, 2011). Therefore, normal tactile perception is necessary for activities of daily living (ADLs) involvement, as well as sociability and recreational activities.

Tactile perception is one sense composing touch, a complex system, with pain perception, temperature perception, proprioception, and kinaesthetic perception (Klatzky & Lederman, 2011; Lederman & Klatzky, 2009). In addition, rehabilitation training for stroke patients involves both actively or passively guided somatosensory discrimination tasks, such as texture, shape, and length discriminations (Fernandes & Albuquerque, 2012). Passive touch refers to conditions in which objects are moved by the experimenter or by a mechanical device against the participant's skin to allow the participant to perceive relevant cues about the object during this passive movement, without any active movement on the part of the participant. Passive touch perception relies only on the cutaneous senses. By contrast, active touch involves voluntary movement from the participant, and uses proprioception, kinaesthesia, and the cutaneous senses. Several studies have compared the exploratory nature of active touch to the receptive nature of passive touch, and have argued that active touch is not equivalent to the simple addition of passive touch and kinaesthesia (Fernandes & Albuquerque, 2012; Gibson, 1962; Guclu & Murat, 2007; Richardson, Symmons, & Accardi, 2000; Richardson, Wullemin, & MacKintosh, 1981; Simoes-Franklin, Whitaker, & Newell, 2011).

Neurophysiological research is in progress to evaluate the effectiveness of tactile perception, including the addition of active movement (Godde, Stauffenberg, Spengler, & Dinse, 2000; Pleger et al., 2003; Richardson, et al., 1981). Godde and colleagues (2000) studied coactivation-based cortical plasticity at psychophysical level in humans, using a tactile stimulation protocol during simultaneous spatial two-point discrimination performance to investigate Hebbian learning for the induction of brain plasticity. Their results demonstrate the potential role of sensory input for the induction of cortical plasticity without the involvement of cognitive factors, such as attention or reinforcement (Godde, et al., 2000). Richardson and colleagues (1981) compared tactile learning of a maze, where the participants in the passive touch condition learned the correct maze path much faster than the participants in the active touch condition. They suggested that

the active touch disadvantage translated into a cognitive limitation but was not a haptic system limitation. They also reported that the active touch condition did not show a performance advantage (Richardson, et al., 1981). Guclu and Murat (2007) also demonstrated that active touch did not produce better performance compared to passive touch in a counting task.

As mentioned, previous studies have examined the dynamic effects of the types of tactile exploration on brain activation and movement learning in healthy children and the adult population (Guclu & Murat, 2007; Juravle, et al., 2011; Simoes-Franklin, et al., 2011). However, there is insufficient evidence to support the effects of tactile exploration on brain activation or motor learning in neurological diseases, such as stroke, traumatic brain injury, traumatic spinal cord injury, Parkinson's disease, and cerebral palsy (Valenza et al., 2001; Van de Winckel et al., 2012, 2013). In particular, therapeutic task programmes can involve actively or passively guided somatosensory discrimination tasks, such as texture, shape, and length discriminations, in rehabilitation settings for stroke populations. Different types of tactile perception have differential benefits on sensory and motor recovery because various tactile perceptions can induce different activations in the same body parts (Van de Winckel et al., 2012).

This study examined the effects of tactile perception on brain activation using electroencephalography (EEG) on two different tactile exploration methods—passive and active touches, in individuals with chronic hemiparetic stroke, and compared the differences of brain responses between those with right and left brain damages. We hypothesized that there would be a significant difference in the two different tactile perception on brain activation during movement, and that the brain activation of the impaired side of the brain (e.g., right or left) would be affected by the two different tactile explorations during movement in the chronic hemiparetic stroke population.

Methods

Participants

Twenty people who were diagnosed with stroke (8 right brain, 12 left brain) participated in this study. The inclusion criteria included: (a) adults who have received a diagnosis of hemiparetic stroke; (b) the onset was > 1 year previously; (c) adults who received 23 points or more on the Mini-mental State Examination (MMSE) (Folstein, Folstein, & McHugh, 1975); and (d) adults who were in Stage 3 or higher in the Brunnstrom's hand function recovery stage. Since the participants were evaluated with the MMSE, the individuals were excluded from this study if they met the following exclusion criteria for the EEG: (a) epilepsy; (b) mental disorders; and (c) sensory impairments. This study was approved by the National Rehabilitation Center Institutional Review Board (IRB management number: NRC-2012-01-003) in the Republic of Korea. All participants provided a written consent after being informed about the study purpose and its procedures.

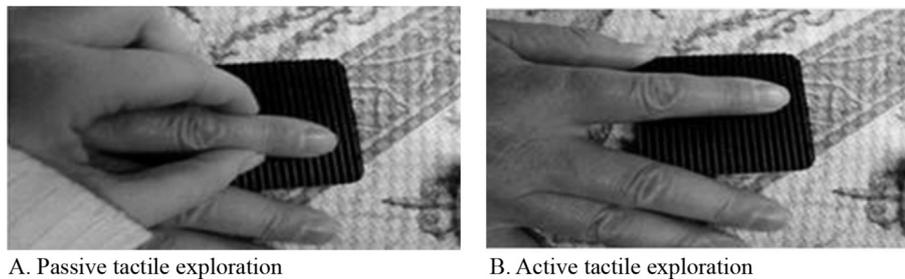


Figure 1 (A,B) The experimental procedure of two different tactile explorations.

Procedure

To minimize any external bias during the experimental process, this study requested that the participants maintained their sitting position without moving and with closed eyes until the experiment was finished. This study then measured their brain waves. The tactile exploration was conducted while the participants were in a sitting position. For the first 3 minutes, we measured the participants' resting EEG, and applied the tactile exploration. The tactile exploration was conducted using two methods: passive exploration and active exploration. The passive exploration was conducted while a tactile board was moved by a therapist and felt by the participant. The active exploration was conducted while the participant actively moved a tactile board (Figure 1). The more affected hand was used for the tactile exploration throughout the experiment in this study.

Outcome measure (experimental equipment)

To determine the neurological changes in the brain, this study measured the brain waves of the participants using a CANS 3000 QEEG-8 (Laxtha, Inc., Daejeon, Republic of Korea), which measured the participants' sensory motor rhythm (SMR) to compare the effects of the tactile exploration tasks. The SMR is activated by somatosensory stimuli and active movement. In addition, alpha, mu, and median (high) beta rhythms were corrected with consciousness, attention without movement, and cognition respectively. This study aimed at evaluating the SMR because it was related to

attention ability in the frontal and occipital lobes, and that the alpha and median beta rhythms might not show relationship with the active movement relatively compared with SMR and mu rhythm. EEG was recorded using Ag/AgCl cup electrodes attached to the scalp at eight active sites (Fp1, Fp2, C3, C4, T3, T4, P3, P4), according to the international 10/20 system. In addition, a relative power analysis was conducted on the values at the eight active positions.

Data analysis

For the EEG analysis, this study collected data on the relative power of each participant SMR. A comparison of the relative power spectrum calculations was conducted using the research task conditions and the Fast Fourier Transform. The SMR was determined using the A1 and A2 sites as the standard electrodes. For a statistical analysis, this study conducted a descriptive analysis and Wilcoxon's signed-rank test using PASW version 18.0 (SPSS Inc., Chicago, IL, USA). The significance was set at $p < .05$.

Results

Table 1 shows the characteristics of the participants. In the right brain damaged stroke group, average age was 64.9 ± 2.9 years, average score of MMSE was 26.8 ± 2.3 points, and average score of Modified Barthel Index was 69.8 ± 29.9 points. In left brain damaged stroke group, average age was 66.4 ± 3.3 years, average score of MMSE

Table 1 General Characteristics of the Participants ($n = 20$).

Characteristic		Right brain damaged ($n = 8$)	Left brain damaged ($n = 12$)	χ^2	p
Sex	Male	6 (75.0)	9 (75.0)	5.337	0.069
	Female	2 (25.0)	3 (25.0)		
Age (y)		64.9 ± 2.9	66.4 ± 3.3	11.667	0.308
Lesion	ACA	3 (37.5)	4 (33.3)	0.506	0.918
	MCA	3 (37.5)	4 (33.3)		
	BA	1 (12.5)	1 (8.3)		
	Etc.	1 (12.5)	3 (25.0)		
MMSE-K		26.8 ± 2.3	25.0 ± 2.2	4.931	0.765
Brunnstrom stage		4.0 ± 1.3	4.0 ± 1.1	5.774	0.329
MBI		69.8 ± 29.9	69.0 ± 26.5	20.000	0.274

Note. Data are presented as n (%) or mean \pm standard deviation. ACA = anterior cerebral artery; BA = basilar artery; MBI = Modified Barthel Index; MCA = middle cerebral artery; MMSE-K = mini-mental state examination–Korean.

was 25.0 ± 2.2 points, and average score of Modified Barthel Index was 69.0 ± 26.5 points (Table 1).

This study measured the relative power of the SMR on prefrontal, central, temporal, and parietal lobes in both the right and left hemispheres to compare the effects of a tactile exploration task using passive and active touches. In participants with right hemispheric damage, the active tactile exploration induced higher relative power of the SMR on the central, temporal, and parietal areas in the right hemisphere compared to the relative power in the passive tactile exploration task. The relative power of the SMR was greater only in the central area during the active tactile exploration compared to the relative power during the passive tactile exploration; however, no brain areas were significantly different between the active and passive tactile explorations (Table 2).

In those participants with left hemispheric damage, the active tactile exploration induced a greater relative power of the SMR on all four sites, including the prefrontal, central, temporal, and parietal areas in the right hemisphere, compared to the relative power in the passive tactile exploration condition. However, the relative power of the SMR was significantly higher on the prefrontal and parietal areas in the right hemisphere. Although the active tactile exploration showed a greater relative power of the SMR in the left hemisphere compared to the relative power in the passive tactile exploration condition, none of the sites were significantly different between the two tactile exploration tasks (Table 2).

Discussion

This study examined the effects of two different tactile explorations, passive and active touches, on EEG brain activation in individuals with right and left brain damage due to stroke. The results of this experiment revealed two

significant findings. First, the relative power of the SMR on the right prefrontal lobe was significantly greater during the active tactile exploration compared to the relative power during the passive exploration in the left damaged hemisphere. Second, the relative power of the SMR on the right parietal lobe was significantly greater during the active tactile exploration compared to the relative power of the passive exploration in the left damaged hemisphere. Most of the measured brain areas showed nonsignificantly higher relative power of the SMR during the active tactile exploration, regardless of which hemisphere was damaged.

Tactile exploration provides important sensory information about objects in ADLs because specialized sensory touch receptors perceive information about pressure, vibration, and movement during daily functions (Gescheider, Guclu, Sexton, Karalunas, & Fontana, 2005; Jones & Smith, 2014). Tactile perception is a necessary modality in clinical tasks in the rehabilitation setting because of its repeated use in daily activities. Previous studies have investigated which methods of tactile perception are beneficial for motor learning and functional improvement in occupational therapy settings (Morris, Henegar, Khanin, Oberle, & Thacker, 2014). A fundamental determinant of occupational performance is the cognition that is related to human information processing, such as sensory detection, sensory identification, attention, motivation, visual perception, memory, and executive functioning. It is also important to consider for improvements in motor re-learning and the cognitive components involved in occupational performance settings (Gillen, 2015; Gillen et al., 2015). Therefore, most stroke cases with difficulty in exploring objects in ADLs can benefit from this tactile exploration.

In recent studies, brain activations that depended on tactile recognition type, attention, and textures differed in the healthy adult population (Kaas et al., 2013; Spitzer & Blankenburg, 2011; Trenner et al., 2008). Those studies reported different tactile explorations depending on the type

Table 2 Value of Sensory Motor Rhythm during Passive and Active Explorations of Participants ($n = 20$).

Damaged hemisphere	EEG area		Mean \pm SD		z	p
			Passive	Active		
Right hemispheric stroke ($n = 8$)	Right	Prefrontal	0.023 \pm 0.026	0.021 \pm 0.011	-0.169	.866
		Central	0.038 \pm 0.016	0.047 \pm 0.029	-0.845	.398
		Temporal	0.044 \pm 0.022	0.053 \pm 0.034	-0.845	.398
		Parietal	0.048 \pm 0.021	0.060 \pm 0.043	-0.676	.499
	Left	Prefrontal	0.030 \pm 0.029	0.024 \pm 0.018	-0.338	.735
		Central	0.051 \pm 0.016	0.052 \pm 0.034	-0.169	.866
		Temporal	0.056 \pm 0.024	0.048 \pm 0.037	-0.507	.612
		Parietal	0.061 \pm 0.023	0.059 \pm 0.034	-0.169	.866
Left hemispheric stroke ($n = 12$)	Right	Prefrontal	0.035 \pm 0.015	0.053 \pm 0.013	-2.589	.010*
		Central	0.044 \pm 0.021	0.047 \pm 0.026	-0.471	.638
		Temporal	0.050 \pm 0.024	0.056 \pm 0.029	-0.471	.638
		Parietal	0.049 \pm 0.023	0.073 \pm 0.029	-2.589	.010*
	Left	Prefrontal	0.035 \pm 0.020	0.042 \pm 0.025	-1.412	.158
		Central	0.054 \pm 0.029	0.066 \pm 0.036	-1.412	.158
		Temporal	0.052 \pm 0.023	0.061 \pm 0.038	-0.549	.583
		Parietal	0.051 \pm 0.027	0.069 \pm 0.055	-1.177	.239

Note. EEG = electroencephalography; SD = standard deviation; SMR = sensory motor rhythm.

* $p < .05$

of stimuli exploration, such as passive or active tactile perception, in a healthy adult population. However, these results have some limitations for their generalization to other pathological conditions. In particular, the cortical activation of stroke survivors is affected depending on the damaged brain areas. [Trenner and colleagues \(2008\)](#) investigated SMR activation and sustained attention in healthy adults. They reported that the superior parietal lobule was involved in tactile object- and action-related representations, and in tactile spatial attention, specifically when attention was focused near the hands, suggesting that SMR was facilitated. [Kaas, van Mier, Visser, and Goebel \(2013\)](#) investigated the neural substrate for working memory of a tactile surface texture during a match-to-sample task. They reported that SMR neurofeedback benefits on sustained attention, working-memory and skilled performance ([Kaas et al., 2013](#)). This study measured the relative power of the SMR using EEG to compare the difference between passive and active tactile explorations.

Previous studies have reported that prefrontal and parietal areas show a sustained response and greater activation during the active exploration of textures in healthy adults ([Campus et al., 2012](#); [Ptak, 2012](#)). They suggested that the activation of prefrontal and parietal areas may indicate voluntary attention. Similar to previous studies, the results of this study also demonstrated that the SMR was significantly raised by active exploration in two brain areas, the right prefrontal and parietal lobes, in participants with a left brain-damaged stroke, compared to passive tactile exploration. Those areas are thought to have important roles in motor imagery, emotion, attention, motivation, and somatosensory associated functions. The brain activation of the right parietal area is also related to tactile attention ([Bolton & Staines, 2011](#); [Kaas, et al., 2013](#)). However, the results of this study showed that the relative power of the SMR was not significantly different between the active and passive tactile explorations in the stroke damaged right hemisphere, although active exploration had greater levels of SMR than passive exploration. The activation of the right hemispheric area is related to tactile attention. In particular, the activation of right parietal area is related to tactile attention, and the right prefrontal cortex influences tactile attention on both sides of the body ([Kaas, et al., 2013](#)). Based on the results, we proposed that there might be no significant differences in the activation of tactile sensation how to explore because of the damage of the area to be responsible for tactile attention with the information related to the sense of touch in patients with right hemispheric damage. Occupational therapists used to consider tactile, perceptual, and cognitive tasks as preparatory activities to perform the optimal activities in clinical settings. The preparatory activities should be the activation of cerebral cortex in individuals with stroke. The results of this study show that the cerebral cortex was activated in active tactile perception more than in passive tactile perception when stroke patients conducted the preparatory activities for rehabilitation, in particular, those stroke patients with left hemispheric damage.

This study had a limitation in that it did not measure any subjective or behavioural responses after each trial of tactile exploration, so there may be a high variability in attention among the participants.

Conclusion

This study confirmed that the brain activation between passive and active tactile exploration is different in stroke patients with left, but not right damaged hemispheres. The SMR had a meaningful difference in this study because of its relationship to the active movement of the human body. This study confirmed that an activation of the brain waves is formed in the right parietal and frontal lobes in left damaged hemisphere. Those areas play key roles in the occupational performance and cognition related to information processing in humans. In future study, the therapeutic approaches using tactile exploration should incorporate brain measurements such as EEG to provide more evidence on the role of tactile perception in daily activities in training by occupational therapists.

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