



# Examining the Process of Visual Cues during Dressing Movements in Patients with Hemiplegia: A Cross-Sectional Pilot Study

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## Research Article

Volume 5 Issue 2

Received Date: April 05, 2022

Published Date: May 03, 2022

DOI: 10.23880/aphot-16000229

## Abstract

**Background:** Reportedly, in patients with hemiplegia, higher brain dysfunction is associated with difficulty in dressing. Nevertheless, it is not clear how patients with hemiplegia take in clothing information (visual information).

**Objective:** This study aimed to compare the process of taking in visual cues during dressing in patients with hemiplegia.

**Methods:** A cross-sectional observational study was conducted on 11 patients with hemiplegia and 11 age- and gender-matched healthy adults. The two groups wore eye mark recorders between 2009 and 2015, and their eye movements were observed as they wore the shirts.

**Results:** The number of fixations per second in patients with hemiplegia was negatively correlated with paralyzed upper limb function ( $r_s = 0.90, p = 0.001$ ). In comparison with the control group, patients with hemiplegia had a higher number of fixations per second ( $p = 0.020$ ), and the ratio of fixation time to movement execution times was also higher ( $p = 0.008$ ). Additionally, whereas the control group more often demonstrated fixation at tags ( $p = 0.001$ ), patients with hemiplegia fixated more often at the body of the clothes ( $p = 0.001$ ) and sleeves ( $p = 0.001$ ), especially fixation on their own nonparalyzed hands ( $p = 0.001$ ).

**Conclusions:** In hemiplegic patients, the more severe the paralysis, the more the patients' movements tended to rely on visual cues. Nevertheless, their perception of visual cues was very inefficient when compared with the control group, suggesting that they disrupted the execution of movements.

**Keywords:** Visual Cues; Hemiplegia; Clothing; Fixation Durations; Fixation Position

## Introduction

Dressing actions are acquired in childhood, and adults perform these actions, almost unconsciously and automatically [1]. Conversely, it has been reported that many patients with hemiplegia after cerebrovascular accidents have difficulty changing clothes [2]. Walker et al. reported

that 76% of therapists felt that "orientating clothing and relating it to body parts was a major dressing difficulty" [3].

There are reasons for difficulty in dressing, for example, problems with higher brain functions, including perception and cognition, such as confusion in motor procedures or the pure inability to orient clothing [4-6]. In clinical practice,

patients with hemiplegia have been observed to move their clothes impatiently to find their sleeves. These behaviors are also observed in patients with hemiplegia without unilateral neglect or loss of dressing, which makes dressing difficult. When observing such situations in our practice, we began to consider that patients with hemiplegia might be taking in different visual information into their brains when they get dressed than healthy people.

Land et al. reported that when people with normal brains attempt to do something, they first look at the object with their eyes to obtain this information, but “objects irrelevant to the task are rarely fixated” [7]. Based on this statement, we hypothesized that the change in fixation during the dressing action in normal subjects may involve a process that facilitates the manipulation of clothing by efficiently incorporating visual cues. If patients with hemiplegia have problems taking in visual information, the problem occurs before the brain can recognize the clothing. However, previous reports have only suggested that problems occur in the cognitive processing process in the brain after the intake of visual information (hemiparetic neglect) or problems in planning and executing movements (dressing apraxia) [8]. Thus, we decided to investigate how visual information is taken in by patients with hemiplegia when they dressed. This study aimed to compare the process of taking in visual cues during dressing in patients with hemiplegia with those of healthy individuals and to elucidate the characteristics. We hope to obtain a better understanding of the factors that contribute to the difficulty in dressing faced by patients with hemiplegia. We will also be able to provide more detailed guidance on how to check the garment.

## Materials and Methods

This study was designed as a pilot cross-sectional observational and analytical study and was conducted from October 2009 to September 2015. Both patients with hemiplegia and controls were fitted with a device for measuring eye movement. We observed and analyzed patients' eye movements while they put on a shirt.

### Participant

Patients with hemiplegia were recruited from among individuals attending the public Okiyama General Hospital. The median age (minimum–maximum) of the participants was 65 (range, 49–79) years in patients with hemiplegia and 63 (range, 36–72) years in the controls. Both groups were required to fulfill the following participation criteria: (1) age between 20 and 80 years, (2) ability to dress themselves independently, (3) near visual acuity of 0.5 or better with the naked eye on the Randolph ring test [9], and (4) ability to

understand instructions given in Japanese. The participation criteria for patients with hemiplegia were as follows: (5) occurrence of only one stroke, (6) no hemorrhage or infarction of the posterior cerebral artery or damage to the posterior cerebral region, and (7) no clinical signs of visual field defects or higher brain dysfunction.

The exclusion criteria were as follows: concomitant degenerative neurologic disease, severe eye disease, history of neurosurgery, severe osteoarticular disease, and severe dementia.

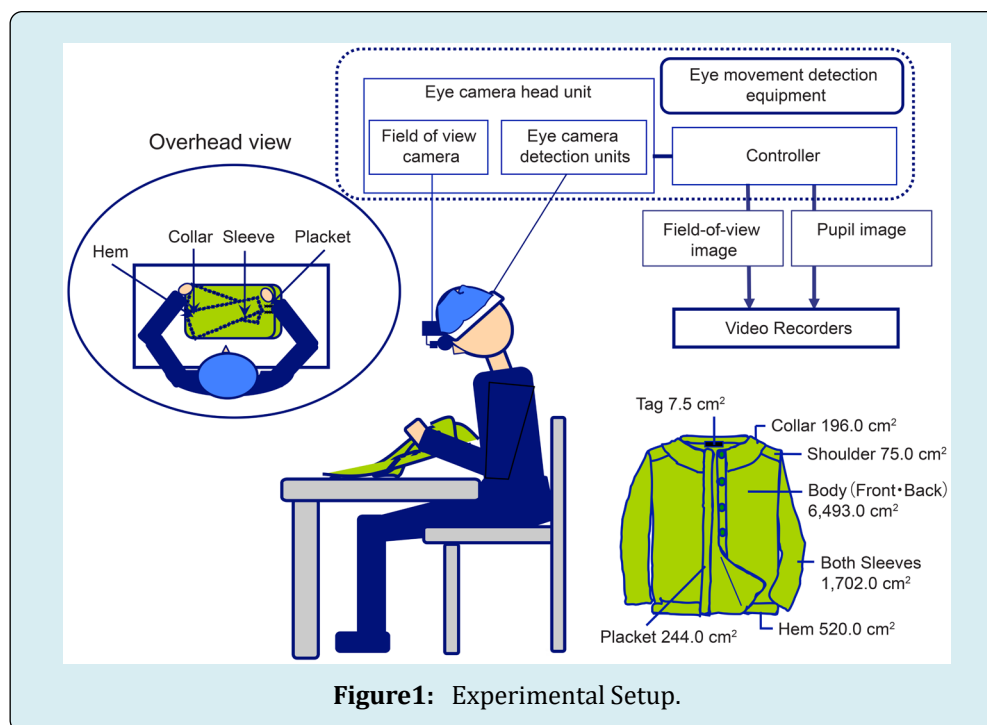
The experiment was conducted according to the Declaration of Helsinki, and prior approval was obtained from the Ethical Review Committees of the Public Okiya General Hospital (02078) and Yamagata Prefectural University of Health Sciences (17-1109). The research collaborators who would serve as participants were informed of the purpose and implementation of the study and provided written consent for research cooperation.

### Mechanical Materials

The experiment was conducted under fluorescent illumination of approximately 1000 lux. The equipment used in this study included an eye movement measurement system (EMR-8B, NAC) comprising three devices: an eye camera attached to the head unit, an eye mark signal (viewpoint position relative to the viewing image) detection unit, and a controller. In this experimental setup, eye movements within a circle of 29.1 cm in diameter were detected, corresponding to an analysis capacity of approximately 1.4 mm. The controller matched the eye mark signal with the field-of-view image sent from the eye camera and output the image along with the pupil image to a connected 640 × 480-pixel monitor (KV-14MF1, Sony Corporation) at 60 Hz. Hence, the temporal and spatial resolutions were 0.017 s and 0.762 mm, respectively. We used EMRd Factory (NAC) as the analysis software for eye movements.

### Task

The experimental task was to unfold a folded yellow-green band collar shirt (hereafter referred to as “the shirt”) and reach into the sleeves. We chose this garment because, although pullover shirts worn over the head have been suggested as a suitable garment for teaching dressing [10], the participants in this study were independent in their dressing. Additionally, we determined that this shirt would require more confirmation from the participants, as it has more components than the pullover shirt does. **Figure 1** shows the schematic diagram of the experimental setup and each part of the shirt and the part to be analyzed.



## Procedure

### Primary outcome measures (eye movements during dressing)

The participants wore the head unit and sat in front of a flat desk that was 70 cm high, with a space of approximately 40 cm in front of them to operate the shirts. Participants were calibrated before the experiment to match their head movements with the eye mark signals and the visual field images captured by the visual field camera, and then, they stood still and waited for the experiment to start.

Just before the start of the experiment, the examiner placed a folded shirt in front of the subject and covered the shirt with a shielding cloth to avoid involving visual information as much as possible. The starting point of the experiment was set at the time at which the examiner removed the shielding cloth with a shout of "please begin." The experiment endpoint was set as the time at which the subject's hand entered the sleeve.

During the experiment, no instructions were given regarding the action procedure, and the participants followed their normal dressing motions. Thus, to avoid prediction, we did not provide the participants with any information about the shirt to be used, except for the instruction, "Please unfold your clothes and put them on." Because the equipment used is able to detect eye mark signals with or without head or trunk movement, no restrictions on head or trunk movement were implemented.

### Evaluation of secondary clinical outcomes (physical and cognitive function tests)

The perceptual evaluation (superficial and deep senses) was performed on all participants. We also conducted perceptual tests on the control group because there are disorders that can occur even if patients are not aware of them, such as peripheral neuropathy [11]. For the perception test, the Semmes-Weinstein monofilament test was performed on the index finger and thumb of the participants, and an evaluator size of  $\leq 3.22$  was considered normal and 3.61–4.31 or less was considered "reduced light touch" [12,13]. Deep sensory testing was performed using the Rivermead Assessment of Somatosensory Performance joint motion and motion direction identification method in 10 directions: one direction at the elbow, four directions at the wrist, and five directions at the fingers [14]. Physical assessment was performed in patients with hemiplegia, including the Brunstrom recovery stage (BRS) of the upper limbs and fingers [15] and the Manual Function Test (MFT) [16]. Additionally, for patients with hemiplegia, as a matter of confirmation, because higher brain dysfunction affects dressing behavior, we administered the line-cutting test of the Behavioral Inattention Test [17] and the visuospatial perception test of the Stroke Injury Assessment Set [18].

## Analysis

The primary outcomes were (1) time of task execution, (2) total fixation duration, (3) average number of fixations per second, (4) average fixation duration per fixation, (5)

fixation position, and (6) ratio of total fixation duration to total motion time. Outcomes 1–4 were analyzed by EMRd Factory. (5) The fixation positions recorded on the video recorder were first analyzed using EMR d Factory because they needed to be corrected for the subject's neck and trunk movements and shirt movements. Next, the data were imported into PowerPoint 2016 using a personal computer (Sony Corporation VAIO PCV-R51) and analyzed after correction with fixation.

Fixation of the viewpoint was defined as a phenomenon in which the viewpoint remains fixed on the object or part of the object [19,20]. Specifically, the eye mark signal was fixed continuously at the same position in the visual field image for more than about 100 ms [21,22]. However, considering the physiological nystagmus of the eye, a visual angle of approximately  $0.2^\circ$  [23] was set as the same position on the PowerPoint. Secondary clinical outcomes were analyzed by examining the relationship between the results of the primary outcomes and the results of the BRS upper extremities and fingers, MFT paralyzed and nonparalyzed sides, line-cutting test, and visuospatial perception test.

### Statistical Analysis

For statistical processing, we performed the chi-square test for gender and used Spearman's correlation coefficient for the relationship between the primary and secondary clinical outcomes of patients with hemiplegia and the relationship between task execution time and total fixation duration. Mann–Whitney U test was used for the comparison of task execution time, number of fixations, fixation duration, and between total task execution time and total fixation duration. The level of significance for each was set at  $p < 0.05$ . The statistical software used was SPSS ver 24.

## Results

### Participant attributes and results of secondary clinical outcomes

**Table 1** shows the attributes of the test participants. Of the 11 patients with hemiplegia, eight had middle cerebral artery infarction and one each of brainstem infarction, subcortical and thalamic hemorrhage. **Table 1** shows the attributes of the patients with hemiplegia and the results of the secondary clinical outcomes.

### Relationship between primary and secondary clinical outcomes of patients with hemiplegia

**Table 2** shows the relationship between the primary and secondary clinical outcomes of patients with hemiplegia. There was a high negative correlation between the number of fixations per second and the BRS upper limb, finger, and MFT paralyzed side.

### Comparison of patients with hemiplegia and control group

**Table 3** shows the results of the comparison of the primary outcomes of patients with hemiplegia and the healthy control group. There were differences in the time of task execution, total fixation duration, average number of fixations per second, and ratio of total fixation duration to motion times.

### Comparison of the number of times and duration of fixations on each part of the shirts

**Table 4** shows the comparison of the number of times and duration of fixations on each part of the shirts. Patients with hemiplegia had a higher number of fixations for the body of the clothes and sleeve but lower for the tag. In terms of fixation duration, patients with hemiplegia had a longer duration of hand, sleeve, and other fixations than the healthy control group did. Nevertheless, they had a shorter fixation duration for tag and placket than the healthy control group did.

### Relationship between task execution and total fixation duration

In patients with hemiplegia, there was a high correlation between total task execution time and total fixation duration (**Figure 2**).

### Comparison of eye movements during the task between patients with hemiplegia and control

**Figure 3** shows examples of eye movements during the task. A shows a patient with hemiplegia (age 49 years, male), and B shows a healthy subject (age 63 years, male). The performance time of each task was 5,247 ms for A and 4,884 ms for B. A frequently fixated on shirts in general and showed multiple fixations at one site. Thus, A often returned to the area after looking at it once. A was also observed to not look at the tag or collar but to look at the nonparalyzed hand that was performing the movement. Conversely, B was often found to be fixated nowhere, even when performing an action. B's eyes then went to the collar and tag, and he never looked at his own hands.

**Figure 3** shows the uptake of visual cues by one patient with hemiplegia (A) and one healthy control (B) during dressing in terms of eye movements and uptake position. The horizontal axis is time (s). The blocks in the second row of the horizontal axis show the movements of the dressing action, and the blocks in the third row show the eye movements during each action. The third row shows the eye movements at each time point, where the diagonal lines are fixations and the black bars are saccades. The dotted blocks are eye movements that cannot be classified. The blocks in the fourth and subsequent lines represent the parts of the shirt and show the eye movements observed during the dressing process.

ID	Age	Sex <sup>*1</sup>	Stroke characteristics <sup>*2</sup>	Date from the onset (Month)	Results of Primary Outcomes			
					Task execution time (ms)	Number of fixations per second	Duration of fixation per time (ms)	Ratio of total fixation duration to task execution time (%)
1	79	M	L MCA distribution	23	12,111	3.1	231	70.6
2	64	M	R MCA distribution	13	10,725	5.1	220	43.1
3	70	F	L Subcortical hemorrhage	36	11,253	2.9	165	57.1
4	65	F	L MCA distribution	14	12,705	2.7	165	61.6
5	58	F	R MCA distribution	16	10,956	3.3	226	68.3
6	78	M	L Brainstem infarction	18	34,485	3.3	211	63.3
7	65	F	R MCA distribution	26	16,698	3.3	190	59.2
8	49	F	L Thalamic hemorrhage	15	5,275	2.9	225	77.4
9	69	F	R MCA distribution	20	20,064	3.3	204	68.3
10	56	M	R MCA distribution	15	16,844	1.4	292	41.7
11	64	F	L MCA distribution	13	11,645	2.1	224	46.2

**Table 1:** Attributes of patients with hemiplegia and primary outcomes of each individual

\*1M: male F: female R: right L: left; \*2MCA: middle cerebral artery

Relationship between the result of primary outcomes and secondary clinical outcomes									
Secondary clinical outcomes	Median (min-max) n = 11	Time of task execution		Total of fixation duration		Number of fixations per second		Duration of fixation time	
		rs	$\rho$ value	rs	P value	rs	P value	rs	P value
BRS U/L	IV(II-V)	-0.03	0.90	-0.27	0.38	-0.85	0.01*	0.25	0.42
BRS Finger	V (II-VI)	-0.08	0.77	-0.33	0.28	-0.76	0.01*	0.00	0.97
MFT Paralyzed side(%)	56.3 (12.5-96.3)	-0.03	0.90	-0.37	0.23	-0.90	0.01*	0.26	0.39
MFT Nonparalyzed side(%)	93.8 (78.1-96.9)	-0.32	0.30	-0.32	0.30	0.33	0.29	0.26	0.40
Line-cutting	9 (8-9)	0.07	0.81	0.37	0.23	0.00	1.00	-0.07	0.81
Test (score)	0 (0-0)	—	—	—	—	—	—	—	—
Visuospatial Perception Test (score)	3(3-3)	—	—	—	—	—	—	—	—

**Table 2:** Relationship between the result of primary outcomes and secondary clinical outcomes

BRS: Brunstrom recovery stage; MFT: Manual function test

Comparison item	Patients with hemiplegia	Controls	P value	r
	Median (min-max)			
Age	65 (49-79)	63 (36-72)	0.22	
Sex (male/female)	5/6	4/7	1.00	
Sensorysuperficial(normal/mildblunted/blunted)	8/2/1	11/0/0	0.18	
Deep (normal/mild blunted/ blunted)	8/1/2	11/0/0	0.18	
Time of task execution (ms)	12,111(5,247-34,485)	5742(4,884-11,979)	0.01	0.81
Total of fixation duration	4,059(7,458-21,815)	1,883(1,108-2,574)	0.01	0.82
Duration of fixation per time (ms)	220 (165-231)	206 (130-292)	0.72	
Number of fixations per second(n)	3.1(1.4-5.1)	2.0(1.3-3.3)	0.02	0.49
Ratio of total fixation time to total motion time(%)	63.2 (43.1-77.4)	43.7 (25.2-72.8)	0.01	0.55

**Table 3:** Comparison of patients with hemiplegia and control group.

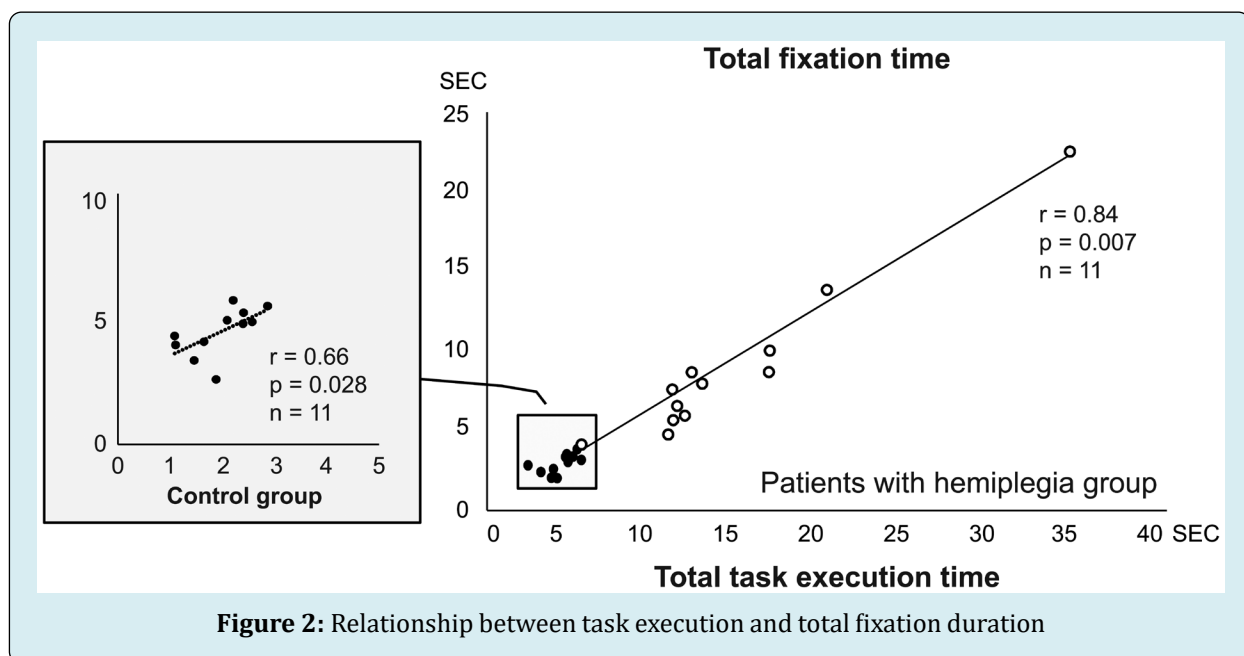
A: Number of fixations

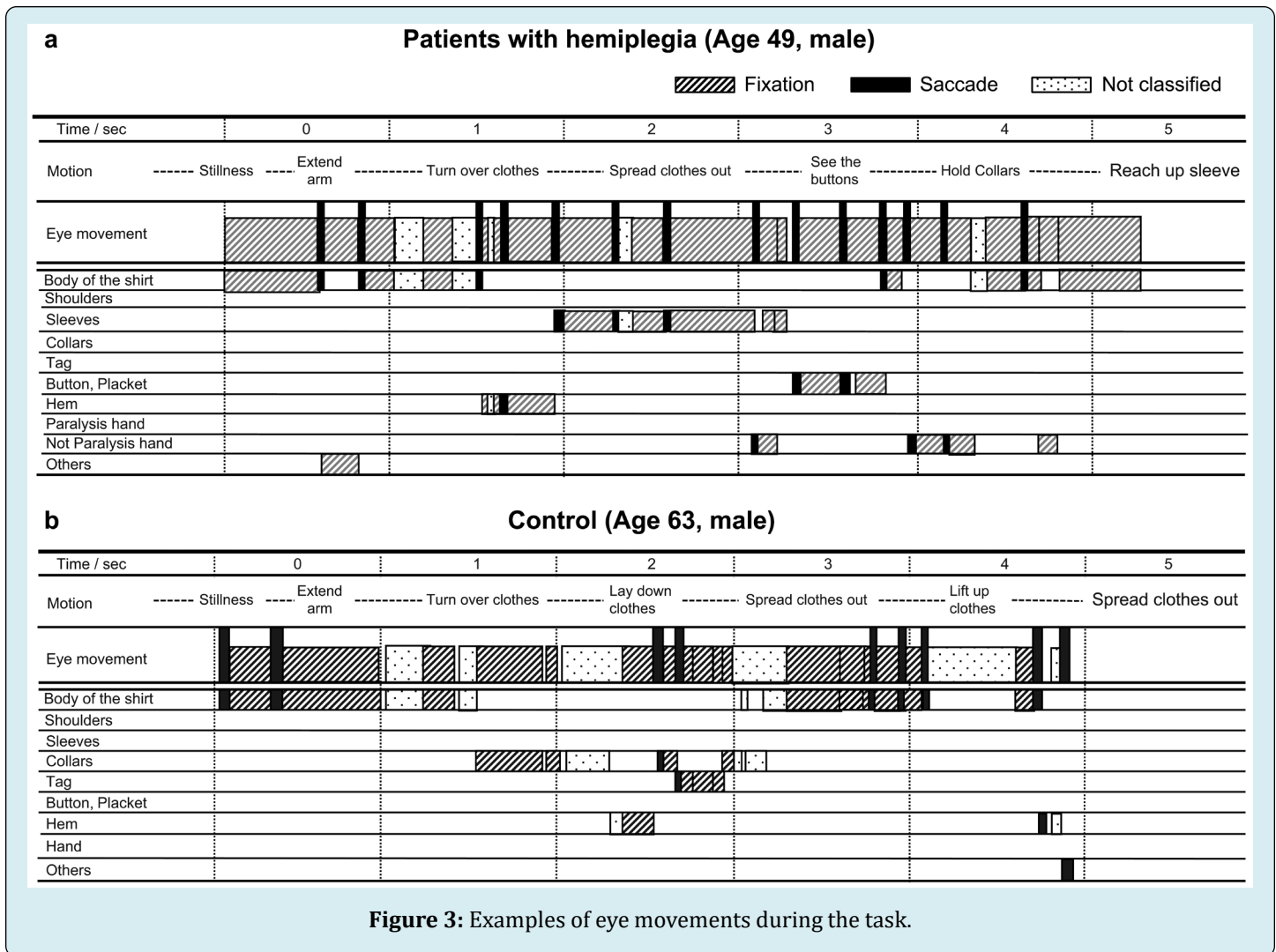


Comparison Item	Patients With Hemiplegia	Control	P Value	r
Body of the clothes	17 (7-33)	6 (4-12)	0.01	0.66
Shoulder	0 (0-3)	0 (0-1)	0.39	
Sleeve	11 (3-37)	1 (0-6)	0.01	0.68
Collars	3 (0-7)	2 (1-5)	0.25	
Tag	0 (0-1)	2 (0-4)	0.01	0.64
Placket	3 (0-8)	2 (0-4)	0.01	0.59
Hem	2 (0-5)	0 (0-7)	0.04	0.42
Hand (not <i>paralysishand</i> )	2 (0-13)	0 (0-1)	0.01	0.72
Others	1 (0-17)	0 (0-3)	0.01	0.61

## B: Duration of fixations(msec)

Comparison Item	Patients With Hemiplegia	Control	P Value	r
Body of the clothes	199 (153-257)	124 (103-194)	0.95	
Shoulder	0 (0-165)	0 (0-132)	0.05	
Sleeve	205 (139-330)	101 (0-132)	0.01	0.56
Collars	125 (0-363)	165 (100-165)	0.69	
Tag	0 (0-99)	154 (0-231)	0.01	0.68
Placket	93 (0-244)	116 (0-393)	0.01	0.58
Hem	33 (0-215)	93 (0-244)	0.04	0.42
Hand (not <i>paralysishand</i> )	132 (0-247)	0 (0-33)	0.01	0.67
Others	173 (0-396)	0 (0-99)	0.01	0.66

**Table 4:** Comparison of the number of times and duration of fixations on each part of the shirt



**Figure 3:** Examples of eye movements during the task.

## Discussion

In this study, we examined the uptake of visual information in patients with hemiplegia and healthy controls during the initial action of dressing.

First, the number of fixations per second in patients with hemiplegia was highly negatively correlated with the motor function of their paralyzed hand but not with the function of the nonparalyzed hand. This is consistent with the assertion of Shingh et al who reported that eye movements in patients with hemiplegia are affected by the status of motor paralysis [24]. Additionally, patients with hemiplegia had a greater number of fixations per second than the control group did. Specifically, most of the control group looked only at the shirt area once or twice, whereas patients with hemiplegia were observed to repeatedly look at the shirt area several times. Although this is the case for right-brain-injured patients, it has been reported that

patients with hemiplegia without hemiplegic neglect should be immobilized more frequently than healthy individuals [25].

Patients with hemiplegia had a higher frequency of fixation on a wide area, such as the torso and sleeves of the garment, and a longer total fixation time, whereas the control group had a higher frequency of fixation to the tags, with a clear difference in the area of concentration. Because the role of fixation in behavioral processes is to extract information [26], we guessed that the control group was able to detect the orientation of the garment, such as inside out, up and down, and left and right, from the small tags. However, patients with hemiplegia did not try to find the small tags. Additionally, they showed a marked tendency to fixate on objects other than shirts. We thought that the reason for this might be that patients with hemiplegia have a lower level of selective attention and divided attention [27]. This led us to speculate that patients with hemiplegia might

have potential attentional deficits that affect their behavior, although not significantly so [28,29]. Furthermore, patients with hemiplegia had a marked fixation on their nonparalyzed hands. Similar to the present study, many previous reports have indicated that patients with hemiplegia looked at their hands during upper limb movements, whereas the control group was able to perform the task without looking at their hands [25,30,31]. The control group has shown the ability to perform the task without directly observing the position of the hand, as long as the sensory information is normal [30].

The high rate of fixation in the patients with hemiplegia is indicative of inadequate visual processing [32]. The total fixation time ratio to the execution time of movements in patients with hemiplegia was generally high. For these reasons, we speculated that because tactile sensations are more sensitive to visual information, patients with hemiplegia might look at their hands in an attempt to directly confirm their movements or to facilitate tactile stimulation by looking at their hands [33-35]. Our results suggest that although patients with hemiplegia rely heavily on visual information for dressing, they also take in a lot of highly biased information because of motor paralysis and poor attention.

### Limitations

This study has some limitations that should be noted. The number of participants was small, and future studies should increase the number of participants. Eye movements were stored in a video camera and analyzed in this experiment, so the time resolution was coarse, and it was difficult to distinguish details such as micro saccades. In terms of fixation time, we did not consider <100 ms as fixation in this study. Thus, it cannot be denied that there were cases of fixation that were <100 ms. We also assumed that more accurate findings will be obtained by more rigorously identifying the damaged area of the brain.

### Conclusion

In patients with hemiplegia, the number of fixations per second was negatively correlated with upper limb function. Conversely, we found a high correlation between total task execution time and total fixation time. Additionally, when compared with the control group, we noted differences in task execution time, total fixation time, average number of fixations per second, and the ratio of total fixation time to movement time. Among patients with hemiplegia, the number of fixations on the garment body and sleeves was higher, and that on the tag was lower.

### Acknowledgments

We would like to express our sincere thanks to all of the participants who participated in this study. For English editing, we received great assistance from ENAGO (Crimson Interactive Pvt. Lt.).

### Declaration of Interest Statement

The authors declare no conflicts of interest associated with this manuscript. The authors have no conflicts of interest directly relevant to the content of this article.

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