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Gaze Direction Recognition Task for the Rehabilitation of Chronic Neck Pain

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Abstract

We developed a mental task with gaze direction recognition (GDR) by which subjects observed neck rotation of another individual from behind and attempted to recognize the direction of gaze. A randomized controlled trial was performed in test (n=9) and control (n=8) groups of subjects with chronic neck pain undergoing physical therapy either with or without the GDR task carried out over 12 sessions during a three-week period. Primary outcome measures were defined as the active range of motion and pain on rotation of the neck. Secondary outcome measures were reaction time (RT) and response accuracy in the GDR task group. ANOVA indicated a main effect for task session and group, and interaction of session (p<0.05). Post-hoc testing showed that the GDR task group exhibited a significant simple main effect upon session, and significant sequential improvement of neck motion and relief of neck pain (p<0.05). Rapid effectiveness was significant in both groups (p<0.01). The GDR task group had a significant session-to-session reduction of RTs in correct responses (p<0.05). Additionally, patients with chronic neck pain showed a significantly longer RT in GDR than healthy volunteers (p<0.01). In conclusion, the GDR task we developed provides a promising rehabilitation measure for chronic neck pain.

Keywords: Gaze direction recognition; Motor imagery; Physical therapy; Chronic neck pain; Cervical range of motion; Reaction time; Accuracy; Healthy volunteers

Introduction

Chronic neck pain refers generally to a painful neck and back lasting longer than six months and is caused by cervical spondylosis deformans, cervical intervertebral disc displacement, or cervical sprain. Conventional therapies include thermotherapy, electric stimulation, and cervical traction [1], and involve soft tissues/joints in the neck in order to alter viscoelastic properties of relevant muscles, increase blood flow, and separate facet joints. These modalities have been evaluated [2-4], but their efficacies remain unclear [5].

There is increasing evidence that chronic pain problems are characterized by alterations in brain structure and function [6]. The pathological mechanism underlying the prolongation of peripheral pain is thought to involve conflict between sensory-motor cortical processing networks [7,8]. A cortical model of long-term pain implicated the neural consequences of incongruence between sensory and visuomotor feedback, or prolonged visuosensory-motor conflict [8]. Evidence exists to suggest that repetitive sensorimotor incongruence may cause changes in neural plasticity of the somatosensory cortex resulting in a reduction of imagery areas and perceptual deficits [9], impairment of physical motor estimation [10,11], and motor programming disorder [12-15]. It has also been reported that motor programming disorder leads to a delay in the reaction times of laterality recognition of both hand and limb which require motor imagery of the relevant organs [12-14], and reduces functional brain activity during motor imagery of the affected limb movements [15].

Moseley [16] hypothesized that preceding mirror therapy with the activation of cortical networks without limb movement would reduce pain and swelling and introduced graded motor imagery to reduce chronic limb pain and disability in patients with complex regional pain syndrome type 1 and phantom limb pain [16,17]. Moseley [17] also described clinical data showing that pain in the limb was reduced as reactions times were shortened in the hand laterality recognition task. Graded imagery initiates recognition of hand laterality and imagery of hand movement, which activates the higher-order motor cortex (premotor cortex). Whilst this does not involve the primary sensory-motor cortex [18], it does result in modifications to the motor imagery program. Thereafter, mirror therapy is performed to activate the primary sensory-motor cortex and facilitate actual motor activity and visual-motor feedback in patients with intracerebral information processing disorder, and to treat chronic limb pain. It has been reported that the clinical application of mirror therapy effectively reduces chronic pain due to phantom limb pain [19], CRPS type I [20] and CRPS type II [21]. These measures were effective for chronic limb pain but not neck pain.

In the current study, we developed a mental motor imagery task by gaze direction recognition (GDR) in which subjects observed neck rotation of another individual from behind and attempted to recognize the direction of gaze. In this procedure, patients with chronic neck pain were forced to experience mental motor imagery. In a previous study, we measured changes of oxygenated hemoglobin (oxyHb) in the cortical blood circulation using functional near-infrared spectroscopy and found that oxyHb concentrations were significantly increased during the GDR task in the premotor area, as well as in the superior temporal sulcus, as compared with those during the action observation of another individual [22]. The GDR task differs from simple action observation in that internally simulated motion of neck rotation is required for the subject together with observation of the another individual's neck rotation. In response to these results, we performed a pseudo-randomized controlled study of cervical

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mobility disorder patients with chronic neck pain by imposing a GDR task of observing the neck rotation of another individual from behind and attempting to recognize the direction of gaze. Our results show that the GDR group was significantly improved in neck pain, as well as in the range of neck rotary motion [23].

However, that study [23] failed to compare the task with physical therapy, thus, its significance compared to other common therapies is unknown. One limitation of the study was that the long-term efficacy of the task was unclear since the study was focused on rapid improvement instead of longer-term results observed with follow-up. The study had another limitation in that it lacked an evaluation of neck motion simulation of the GDR group, including response time (RT) and the rates of correct answers. Therefore, it remains unclear whether the improvement of motion simulation actually resulted in the relief of neck pain.

Accordingly, we subjected cervical motility disorder patients afflicted with chronic neck pain with GDR, in addition to basic physical therapy, in a randomized controlled study, performed a longer follow-up, and performed a time-course evaluation of the effects of GDR on RT and rates of correct answers. We compared the effects of GDR between these patients and healthy volunteers to verify an anticipated reduced GDR effects in these patients, who were assumed to have impaired motion simulation of the neck compared to healthy volunteers.

Methods

Study design and subjects

A pilot randomized controlled study was designed to test whether a newly developed gaze direction recognition task could be of potential advantage in the treatment of chronic neck pain. One hundred and twenty patients were recruited over a one-week period (March 7 to March 13, 2011) from the Outpatient Department at the Department of Rehabilitation, Higashi-Osaka Yamaji Hospital, and Midori Clinic (Osaka, Japan). Inclusion criteria in this study were motility disorder in the neck of more than six months' duration with chronic pain and limited range of motion in the neck. Exclusion criteria included cervical or systemic inflammatory signs, and histories of surgery in the neck, neural blockage therapy, exercise therapy in the neck, and medications for neck symptoms. According to these criteria, 103 of the initial 120 patient cohort were excluded, and the remaining 17 patients participated as test subjects in this study. Written informed consent, in accordance with the guidelines of the Declaration of Helsinki, was obtained from the 17 subjects prior to the first experimental session. Figure 1 shows a schematic explanation of enrollment and allocation of subjects, follow-up, and data analysis. Table 1 summarizes sex, age, disease and duration, physical therapy given, and the active range of motion and the degree of pain upon neck rotation in each subject.

All 17 subjects were allocated to two groups according to a computer-generated random number. The gaze direction recognition task group (GDR task group, n=9) underwent physical therapy and GDR task sessions as described below. A control group (n=8) received physical therapy but did not undergo the GDR task.

Primary outcome measures included active range of motion and cervical pain, as measured by a 100 mm visual analog scale, upon right and left rotation of the neck. Secondary outcome measures in the GDR task group included reaction time and the accuracy of responses in the GDR task.

A single session involving an interventional procedure was

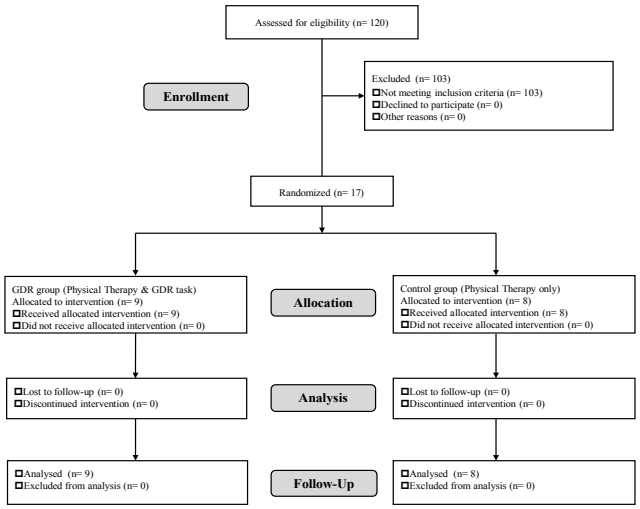
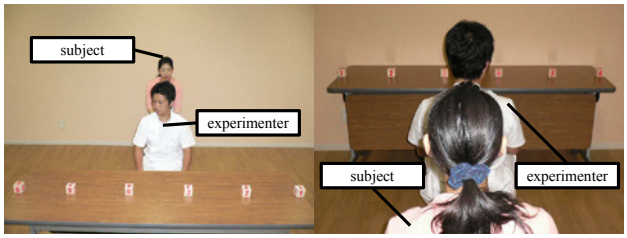


Figure 1: Randomization and allocation of subjects and experimental protocol.



Each column represents the positional relationship between a subject and an experimenter with six numbered boxes. The subject is positioned behind the experimenter and views neck rotation of the experimenter who attempts to gaze randomly at one of six boxes placed on the table, and imagines which one of the boxes the experimenter directs his gaze upon. The subject was then asked to give a verbal response as to the box number of the experimenter's gaze direction.

Figure 2: Experimental design of gaze direction recognition task.

carried out as follows. After a routine physical check-up, carried out by a physician, all subjects were evaluated for the active range of motion and cervical pain upon rotation of the neck. Thereafter, subjects were administered physical therapies. Subsequent to this, the GDR task group, but not the control group, underwent a GDR task. Finally, all subjects in the two groups were assessed for active range of neck motion and evaluated for pain on neck rotation.

A total of 11 interventional sessions were performed over a total period of three weeks. A follow-up assessment was carried out 15 days after the last session.

This study was approved by the ethics committee of the Moujin-kai medical corporation (approval number: H22-12) and Kio University Health Science Graduate School (approval number: H19-12). All of the subjects signed a consent form after being informed of the study in compliance with the Helsinki Declaration.

Procedure

The 9 subjects belonging to the GDR task group underwent a specific task following physical therapy (Figure 2). An experimenter sat 75 cm apart from a subject, and the subject was asked to observe the experimenter from behind. A table (1800 mm×400 mm) was placed 75 cm in front of the experimenter, on which six blocks, numbered 1 to

Sex (M/F)	Age (years)	Disease	Duration (days)	Physiotherapy	right aROM (°)	left aROM (°)	right pain VAS (mm)	Left pain VAS (mm)
F	65	cervical spondylosis	372	cervical traction & Microwave therapy	40.2	50.5	72	44
M	47	cervical sprain	249	cervical traction	40.7	40.2	83	76
F	16	cervical sprain	261	cervical traction & Microwave therapy	45.2	60.2	68	43
M	61	Cervical spondylosis	269	cervical traction & Microwave therapy	30.3	50.1	63	46
M	52	cervical spondylosis	198	cervical traction & Microwave therapy	42.3	46.2	53	36
F	55	cervical spondylosis	272	cervical traction & Microwave therapy	50.4	38.4	42	58
F	74	cervical spondylosis	207	cervical traction & interferential current	35.2	40.6	62	66
M	32	cervical sprain	311	cervical traction & Microwave therapy	20.6	45.4	90	7
M	51	cervical spondylosis	269	cervical traction & Microwave therapy	39.5	46.2	62	57
GDR group mean (SD)	50.3(17.5)		267.6(52.1)		38.3(8.7)	46.4(6.7)	66.1(14.5)	48.1(19.9)
F	35	cervical sprain	216	cervical traction & Microwave therapy	44.2	55.4	69	23
M	65	cervical spondylosis	232	cervical traction & Microwave therapy	40.3	44.1	66	54
M	70	cervical spondylosis	239	cervical traction & Microwave therapy	52.3	42.3	1	52
M	43	cervical sprain	198	cervical traction & Microwave therapy	30.4	38.1	78	65
F	61	cervico brachial syndrome	392	cervical traction & interferential current	54.2	36.3	28	72
F	52	cervical spondylosis	337	cervical traction & interferential current	48.4	41.6	63	66
F	51	cervical spondylosis	217	cervical traction & Microwave therapy	50.2	49.3	52	45
M	58	cervical spondylosis	292	cervical traction & Microwave therapy	51.1	52.4	52	54
Control group mean (SD)	54.4(11.6)		265.4(68.7)		46.4(7.9)	44.9(6.8)	51.1(25.2)	53.9(15.3)

[a]ROM=active range of motion; VAS=visual analog scale for pain assessment. right [a]ROM: active range of motion of rotation of the neck to the right before the first intervention; left aROM: active range of motion of rotation of the neck to the left before the first intervention; right pain VAS: pain visual analog scale on right rotation of the neck before the first intervention; left pain VAS: pain visual analog scale on left rotation of the neck before the first intervention. GDR group, mean (standard deviation); control group, mean (standard deviation). In each variable, there was no significant difference between the two groups

Table 1: Patient sex, age, disease, duration of disease, physical therapy, aROM and pain VAS before the first intervention.

Experimental session																									
			Session 1	Session 2		Session 3		Session 4		Session 5		Session 6		Session 7		Session 8		Session 9		Session 10		Session 11		Session 12	
GDR group (n=9)	right rotation aROM (°)	Pre	38.3	43.3		48.4		50.4	*1	55.5	**1 *2	56.6	**1 *2	55.5	**1 **2 *3	56.5	**1 *2 *3	59.5	**1 **2 **3 *4	60.3	**1 **2 **3 **4	63.0	**1 **2 **3 **4	62.5	**1 **2 **3 **4
		SD	8.7	7.8		9.1		6.4		8.2		9.1		8.7		11.3		6.3		5.3		4.7	*7	4.6	
	left rotation aROM (°)	Pre	46.4	50.5		53.2		57.2.	*1	57.5	**1	58.6	**1 **2 **3	58.1	**1 *3	59.6	**1 **2	61.8	**1 **2 **3	61.8	**1 **2	61.8	**1 **2 *3	62.4	**1 **2 **3
		SD	6.7	7.9		9.5		11.9		10.1		9.4		11.0		9.1		4.8		4.5		7.4		4.5	
	right rotation pain VAS (mm)	Pre	66.1	44.3		30.9		17.8		16.0		18.3		20.3		21.3		6.6		10.4		11.3		6.6	
		SD	14.5	23.7	**1	20.1	**1	26.1	**1	19.5	**1 *2	30.8	**1	25.1	**1	22.8	**1	5.3`	**1 **2 **3	21.1	**1 **2 *3	18.2	**1 **2	8.5	**1 **2 **3
	left rotation pain VAS (mm)	Pre	48.1	32.8		26.9		23.1		15.8		17.0		11.2		13.2		9.8		12.6		12.6		6.6	
		SD	19.9	16.3		16.4	**1	32.5		16.6	**1	17.0	**1	9.9	**1 **2	10.7	**1 **2	8.1	**1 **2	11.3	**1	24.1	**1	8.6	**1 **2 *3
Control group (n=8)	right rotation aROM (°)	Pre	46.4	44.3		45.7		45.7		45.6		46.6		46.0		46.7		47.2		46.0		46.7		47.5	
		SD	7.9	7.2		7.8		10.4		7.3		8.2		7.7		8.0		7.1		7.4		7.8		7.6	
	left rotation aROM (°)	Pre	44.9	43.7		44.8		44.9		45.2		45.3		46.2		44.8		46.1		45.7		45.3		45.8	
		SD	6.8	6.2		7.2		5.9		5.8		5.3		6.0		5.7		5.1		5.3		5.5		5.7	
	right rotation pain VAS (mm)	Pre	51.1	50.0		48.1		47.6		51.4		47.6		47.9		48.5		44.4		48.0		46.9		41.6	
		SD	25.2	24.0		21.8		22.9		23.6		23.1		24.4		25.0		22.4		26.0		23.6		22.0	
	left rotation pain VAS (mm)	Pre	53.9	53.5		52.6		52.1		50.9		49.5		46.4		51.1		47.4		47.6		46.6		46.5	
		SD	15.3	16.5		17.9		11.8		12.1		13.3		13.7		15.8		10.6		10.9		11.1		10.1	

[a]ROM=active range of motion; VAS=visual analog scale for pain assessment. Pre=average in measurements before task; SD=standard deviation in measurements. * Significance in two-way repeated-measures ANOVA and factorial analysis of session by Bonferroni ad hoc test. *: 0.05; **: <0.01. The numbers after * represent the number of task session. In all parameters, the GDR task group showed significant sequential improvement, while the control group did not.

Table 2: [a]ROM and pain VAS in the GDR task group and control group, measured before each experimental session.

6, were placed in regular intervals. Subjects were able to watch all of the blocks. The experimenter's gaze changed to either one of the six numbered blocks in a random manner by voluntary eye movement and rotation of the neck. The experimenter initiated the performance following a specific signal by an assistant to the experimenter. The experimenter maintained gaze at a certain numbered box until the subject gave a response. Then, the subject observed the experimenter's neck rotation from behind and was asked to imagine the block at which the experimenter was gazing and to provide a verbal response as to which imagined block the subject was gazing at as quickly as

	GDR group				Control group			
	right aROM	left aROM	right VAS	left VAS	right aROM	left aROM	right VAS	left VAS
Pre	54.1	57.4	22.5	19.1	46.2	45.2	47.8	49.8
SD	7.7 *	5.0 *	17.4 *	11.9 *	0.8 *	0.7 *	2.7 *	2.9 *
Post	57.7	60.3	16.5	11.8	49.3	46.1	38.3	39.4
SD	6.0	3.4	14.0	5.8	1.0	1.2	3.0	2.9

* paired t-test, $p<0.01$

Table 3: Active range of motion and pain assessment before and after gaze direction recognition in the task group and control group.

Experimental session												
	Session 1	Session 2	Session 3	Session 4	Session 5	Session 6	Session 7	Session 8	Session 9	Session 10	Session 11	Session 12
Correct RT (m sec)	1722.9	1501.0	1465.9	1300.9	1361.3	1482.8	1411.6	1312.2	1316.0	1127.2*	1263.8	1121.9*
SD	558.7	446.8	345.4	234.9	380.9	464.1	287.2	280.8	190.9	130.6	323.3	90.7
Accuracy (%)	93.0	94.4	93.0	96.3	95.6	94.1	95.6	98.1	97.8	99.6	99.3	100.0
SD	6.1	6.5	8.6	5.4	5.3	7.0	7.5	4.4	4.7	1.1	2.2	0.0

Correct RT=reaction times in correct recognition. Accuracy=response accuracy in the GDR task group. Sequential data from session 1 to session 12; mean and standard deviation (n=9). * One-way ANOVA ($p<0.05$)

Table 4: Sequential reaction time data for the correct recognition of the experimenter's direction of gaze and response accuracy in the GDR task group.

Sex (M/F)	Age (years)	right aROM (°)	left aROM (°)	right pain VAS (mm)	Left pain VAS (mm)	Correct RT (msec)	Accuracy (%)
F	65	40.2	50.5	72	44	3023.9	86.7
M	47	40.7	40.2	83	76	1607.1	100.0
F	16	45.2	60.2	68	43	1840.8	83.3
M	61	30.3	50.1	63	46	1475.5	93.3
M	52	42.3	46.2	53	36	1341.4	100.0
F	55	50.4	38.4	42	58	1332.8	90.0
F	74	35.2	40.6	62	66	1339.0	90.0
M	32	20.6	45.4	90	7	1408.2	93.3
M	51	39.5	46.2	62	57	2137.0	100.0
GDR group mean (SD)	50.3(17.5)	38.3(8.7)	46.4(6.7)	66.1(14.5)	48.1(19.9)	1722.9(558.7)	93.0(6.1)
F	65	68.3	72.4	0	0	1046.0	96.7
M	47	72.5	73.0	0	0	1106.1	93.3
F	16	88	88.4	0	0	1054.5	96.7
M	61	49	65.0	0	0	1057.0	93.3
M	52	60	62.4	0	0	1002.8	90.0
F	55	54.4	51.7	0	0	854.5	93.3
F	74	68.2	69.1	0	0	1161.3	90.0
M	32	68.2	75.5	0	0	1256.1	93.3
M	51	57.3	60.0	0	0	859.9	90.0
Healthy volunteer s group mean (SD)	50.3(17.5)	65.1(11.6)	68.6(10.5)	0.0(0.0)	0.0(0.0)	1044.2(129.6)	93.0(2.6)

Both groups were adjusted for age and sex. Left and right aROM were significantly reduced in the GDR group compared to the healthy volunteer group ($p<0.01$), while left and right pain VAS were significantly increased in the GDR group compared to the healthy volunteer group ($p<0.01$). In GDR, although there was no significant difference in accuracy between the two groups ($p>0.05$), the GDR group showed significantly prolonged correct RT compared to the counterpart group ($p<0.01$)

Table 5: Means and standard deviations of aROM, pain VAS, correct RT, and accuracy in the GDR and healthy volunteer groups.

possible. Whether the subject's recognition of the experimenter's gaze of direction was correct was not fed-back to the subject until the end of the experiment. An assistant to the experimenter recorded the reaction times and correctness of the response. A single experimental GDR task consisted of 30 trials of the task outlined above, which was carried out in about 10 minutes.

The subjects were instructed not to move their body during the GDR task. To monitor the subjects' behavior during the GDR task, electromyography (Biometrics Ltd, USA) was recorded from the sternocleidomastoid muscle and analyzed using the TRIAS System (DKH Ltd, Japan).

Subjects of both the GDR task and control group received physical therapies, consisting of either one of three therapeutic modalities: cervical traction (n=17), microwave therapy (n=13), or interferential current (n=3). Physical therapy modality was selected by the physician (Table 1) and performed by physical therapists who were unaware of the allocated group.

Primary outcome measures

Active range of cervical rotation motion was measured using a Goniometer (Q110, Biometrics Ltd) according to the measurement method of active range of motion that was recommended in 1995 by the Japanese Orthopaedic Association and the Japanese Association of Rehabilitation Medicine, based upon methods described by the American Academy of Orthopaedic Surgeons (1965). Measurements were analyzed using the TRIAS System (DKH Ltd). Subjects sat in a chair, and a vertical line connecting the bilateral acromion was defined

as the primary reference axis, whilst a line connecting the bridge and occipital tubercle was defined as the rotational reference axis. During measurements of active range of motion upon neck rotation, the assistant sustained the subject's posture in order to maintain the trunk to form the basic axis. Active range of motion in neck rotation to the right and neck rotation to the left was each measured three times, and the third measurement was recorded for analysis.

Neck pain was assessed using the 100 mm visual analog scale (VAS). The subject was asked to mark the horizontal line of the scale according to the strength of pain after he or she rotated the neck to either the right or left. The left end of the scale was defined as no pain and the opposite right end of the scale was defined as maximum. The subject was not informed about previous measurements at the time of post-task measurement.

Active range of motion evaluation and VAS pain assessment were performed before and after each interventional session in both the GDR task group and control group.

Measurements were taken in an examination room by one experimenter, an assistant to the experimenter, and one recorder. They were not informed of the assignment of subject group.

Secondary outcome measures

In the GDR task group, response reaction time and accuracy of GDR task (number of correct answers/total number of answers×100) were determined. The reaction times between the starting signal by an assistant and the subject's response was measured using a stop-watch at an order of milliseconds. Reaction times for the correct recognition of gaze direction were selected for further analyses.

Comparisons between the GDR group and the healthy volunteer group

We evaluated the correct RT, as well as the accuracy in the GDR task, which was given to 9 subjects each of the GDR group and the age/sex-matched healthy volunteer group at the same time as the randomized controlled study. Inclusion criteria for healthy volunteers were being free of current and past motility disorders or pain of the neck.

The healthy volunteers underwent the same GDR as the randomized controlled study after they were evaluated for aROM of neck rotation and concomitant neck pain upon motion. Correct RT and accuracy were measured in the GDR task.

The healthy volunteer group was evaluated only in one session for aROM, neck pain, and RT/accuracy in GDR in the same way as the randomized controlled study.

Statistical analyses

Statistical analyses were performed using SPSS for Windows and an alpha level of 5% was considered as statistically significant.

Age and disease duration at the first experimental session, and active range of neck motion and VAS pain assessment before intervention were compared between the GDR task group and the control group using the unpaired *t*-test. Sex, disease entity, and physical therapy were compared between the GDR group and the control group using the chi-squared test.

The outcome measures of the active range of motion and VAS pain assessment upon lateral neck rotation were analyzed using two-way ANOVA for two binary factors, i.e., group (GDR task group and control group) and task session (12 sessions). The Bonferroni method was used for post-hoc testing.

In order to analyze the rapid efficacy of intervention, active range of motion and VAS pain assessment before and after intervention were compared between the GDR group and the control group using a paired *t*- test.

To evaluate the sequential changes of gaze direction recognition ability associated with repetitive GDR task achievement, session-to-session measurements of reaction times for correct recognitions (12 sessions) and accuracy of responses (12 sessions) in the GDR task group were statistically analyzed using one-way ANOVA and the Bonferroni method with post-hoc testing.

In the GDR task group, correlations between reactions times and correct recognitions, accuracy of responses, active range of motion, and VAS pain assessment in cervical rotations, were determined using the Pearson correlation coefficient.

Student's *t*-test was used to compare a ROM, pain VAS, and correct RT/accuracy in one session of GDR between the GDR group and the healthy volunteer group.

Results

None of the 17 subjects in either the GDR group or the control group withdrew from the study (Figure 1). Electromyographies in the bilateral sternocleidomastoid muscles demonstrated that all subjects of the GDR task group remained stable in the cervical muscles during the GDR task sessions.

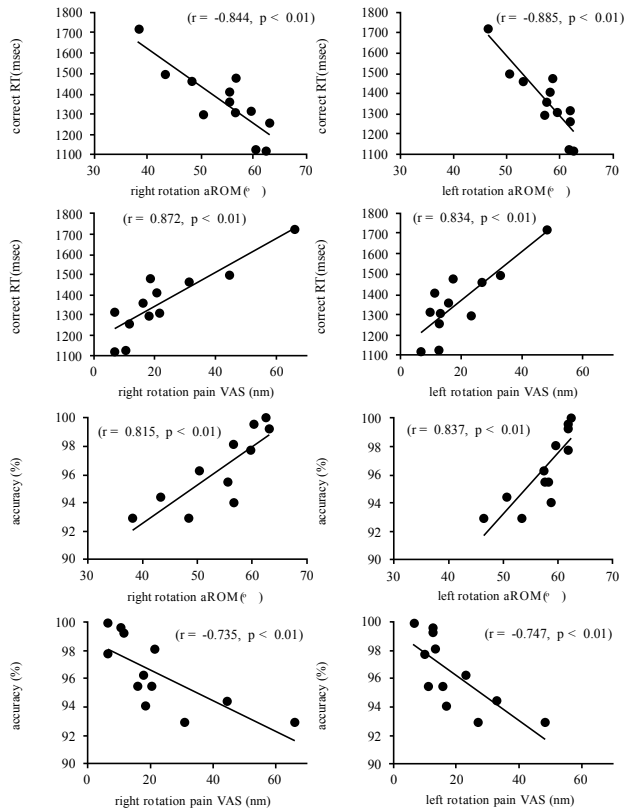
Baseline data

Table 1 shows patient sex, age, disease, disease duration, type of physical therapies given, and active range of motion and VAS pain assessment on neck rotation before interventions. The unpaired t-test revealed no significant difference between the GDR task group and the control group in terms of age and disease duration at the time of the first interventional session (age: 95% confidence interval (CI) 11.5 to - 19.6, p>0.05; disease duration in days: 95% CI 64.7 to - 60.4, p>0.05; right rotation aROM: 95% CI 0.5 to - 16.8, p>0.05; left rotation aROM: 95% CI 8.5 to - 5.5, p>0.05; right rotation pain VAS: 95% CI 35.9 to -6.0, p>0.05; left rotation pain VAS: 95% CI 12.8 to -24.3, p>0.05). Chi-squared tests for sex, disease, and physical therapy showed no significant difference between the GDR task group and control group (sex: X^2=0.0525, p>0.05; disease: X^2=1.2364, p>0.05; physical therapy (physiotherapy): X^2=0.4392, p>0.05).

Table 2 show sequential changes and statistical analyses of active range of motion and pain VAS when subjects rotated their necks to the right or left. Table 3 shows the active range of motion and pain assessment before and after the task, along with associated statistical analysis.

Active range of motion on neck rotation to the right

Statistical analyses using two-way repeated-measures ANOVA showed a significant main effect of group, F (1, 15)=6.177, p<0.05, a main effect of interventional session, F (4.797, 71.952)=14.335, p<0.01, and a significant interaction effect between group and interventional session, F (4.797, 71.952)=11.051, p<0.01. The GDR task group had a significant main effect of interventional session, GDR task group F (11, 5)=27.768, p<0.01; Control group F (11, 5)=0.180, p>0.05. Post-hoc tests indicated significant sequential improvement in the GDR task group, but not in the control group (Table 2).



Left columns: right rotation of the neck; right columns: left rotation of the neck. The data indicate significant correlations in all (p<0.01)

Figure 3: Correlation data between rotation of the neck and reaction times for correct answers and those between pain assessment and accuracy of responses in the GDR task group.

As regards rapid effectiveness, both the GDR group and control group showed a significant improvement, GDR task group: 95% CI -2.8 to - 4.4, p<0.01; control group: 95% CI -1.7 to -3.7, p<0.01 (Table 3).

Active range of motion on neck rotation to the left

Statistical analyses using two-way repeated-measures ANOVA showed a significant main effect of group, F (1, 15)=15.059, p<0.01, a main effect of interventional session, F (3.616, 54.237)=9.429, p<0.01, and a significant interaction effect between group and interventional session, F (3.616, 54.237)=6.626, p<0.01. The GDR task group had a significant main effect of interventional session, GDR task group F (11, 5)=18.697, p<0.01; Control group F (11, 5)=1.206, p>0.05. Post-hoc tests indicated significant sequential improvement in the GDR task group, but not in the control group (Table 2).

As regards rapid effectiveness, both the GDR group and control group showed a significant improvement, GDR task group: 95% CI -2.2 to -3.6, p<0.01; control group: 95% CI -0.3 to -1.1, p<0.01 (Table 3).

VAS pain assessment upon right rotation of the neck

Statistical analyses using two-way repeated-measures ANOVA showed a significant main effect of group, F (1, 15)=7.398, p<0.05, a main effect of interventional session, F (3.937, 59.062)=12.477, p<0.01, and a significant interaction effect between group and interventional session, F (3.937, 59.062)=8.374, p<0.01. The GDR task group had a significant main effect of interventional session, GDR task group F (11, 5)=18.601, p<0.01; Control group F (11, 5)=1.318, p>0.05. Post-hoc tests indicated significant sequential improvement in the GDR task group, but not in the control group (Table 2).

As regards rapid effectiveness, both the GDR group and control group showed a significant improvement, GDR task group: 95% CI 8.1 to 4.0, p<0.01; control group: 95% CI 10.4 to 6.7, p<0.01 (Table 3).

VAS pain assessment upon left rotation of the neck

Statistical analyses using two-way repeated-measures ANOVA showed a significant main effect of group, F (1, 15)=27.183, p<0.01, a main effect of interventional session, F (3.757, 56.356)=8.143, p<0.01, and a significant interaction effect between group and interventional session, F (3.757, 56.356)=3.614, p<0.05. The GDR task group had a significant main effect of interventional session, GDR task group F (11, 5)=4.945, p<0.05; Control group F (11, 5)=0.423, p>0.05. Post-hoc tests indicated significant sequential improvement in the GDR task group, but not in the control group (Table 2).

As regards rapid effectiveness, both the GDR group and control group showed a significant improvement, GDR task group: 95% CI 9.8 to 4.8, p<0.01; control group: 95% CI 11.8 to 6.9, p<0.01 (Table 3).

Reaction times in correct recognition and accuracy of responses in the GDR task

Table 4 shows session-to-session sequential changes in reaction times for correct answers and the accuracy of responses in the GDR task group. One-way ANOVA revealed that the reaction times for correct answers exhibited a significant reduction decrease session 1 and session 10 (95% CI 1150.7 to 40.6, one-way ANOVA, p<0.05) and between session 1 and session 12 (95% CI 1156.0 to 45.9, one-way ANOVA, p<0.05). There was no significant sequential change in the accuracy of responses.

Correlation analyses

Figure 3 illustrates reaction times for correct answers versus the active range of motion upon neck rotations, reaction times for correct answers versus pain assessment upon neck rotations, accuracy of responses versus active range of motion upon neck rotations, and the accuracy of responses versus pain assessment upon neck rotations.

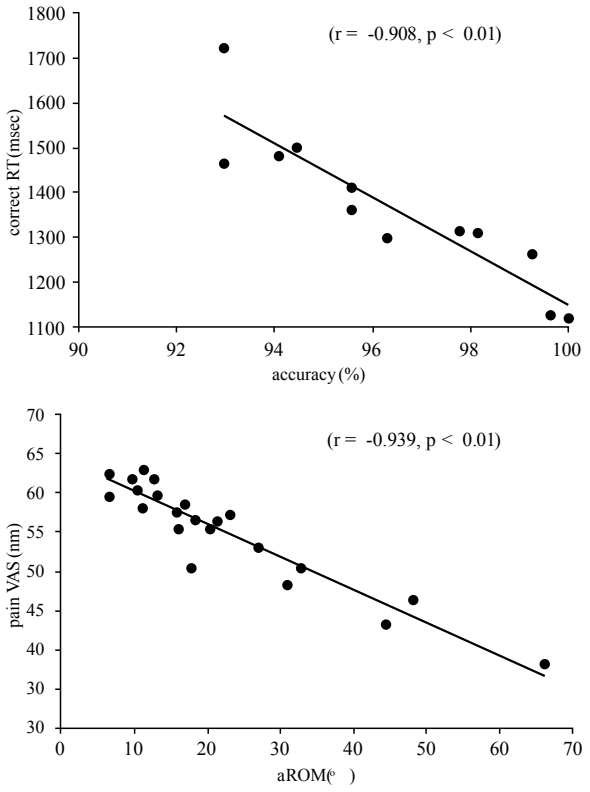
Figure 4 shows reactions times for correct answers versus the accuracy of responses, and the active range of motion versus pain assessment upon neck rotation. These data were obtained from the GDR task group, and all relationships indicate significant correlations (p<0.01).

Comparisons between the GDR group and the healthy volunteer group

Means, standard deviations of the above individual parameters, and results of their statistical analyses in both groups are shown in table 5. The results show that aROM upon right or left rotation was significantly reduced in the healthy volunteer group compared to the GDR group (p<0.01), while pain VAS upon right or left rotation was significantly increased in the GDR group compared to the healthy volunteer group (p<0.01). While there was no significant difference in correct RT/accuracy in GDR between the two groups (p>0.05), correct RT was significantly prolonged in the GDR group (p<0.01).

Discussion

When the GDR and healthy volunteer groups were compared, the former group with chronic neck pain showed significantly prolonged correct RT in GDR, suggesting that patients with chronic neck pain have difficulty in motion simulation of the neck.



Data indicate significant correlations in all parameters (p<0.01)

Figure 4: Correlation data between the accuracy of response and the reaction times for correct answers, and correlative data between active range of motion and pain assessment of the neck.

Results from the GDR task of the randomized controlled study revealed significant sequential relief of chronic neck pain as assessed by the visual analog scale (VAS). Furthermore, an inter-group statistical comparison indicated that the improvement of VAS pain assessment was significant in the GDR task group as compared with the control group without the GDR task. Moseley reported that the hand laterality recognition task reduced pain and disability together with reduced reaction times in the task for patients with chronic hand pain [16,17]. Similar beneficial effects are likely to be the case for our current results in that the GDR task produced a sequential reduction in reaction times for correct recognition of another individual's direction of gaze and significant correlates of reduced reaction times and accuracy of responses were associated with improvement of chronic neck pain. Action observations of the experimenter's neck rotations prompt affected subjects to imagine the direction of gaze and to induce precise motor imagery of the neck [24]. Action observations of neck rotations in a healthy experimenter without neck disease may produce neural motor images and activate neck-specific-motor representations in the cortex [25].

Our control group showed rapid improvement in the active range of motion and pain in neck rotation, although this improvement did not remain long. A previous study on the effects of cervical traction reported subjective relief of neck pain as late as 12 hours after intervention [26], suggesting that traction therapy provides rapid effectiveness. However, physical therapies provide only short-term improvement in neck pain and active range of motion, and such treatment modalities are not sufficient to achieve frequently performed cervical motion in daily life according to the cervical motion program after neck damage. In the GDR task group, programming for precise cervical motion was facilitated together with rapid peripheral effectiveness by physical therapies as in the control group, which must have been responsible for the persistent effectiveness revealed by follow-up examination 15 days after intervention in the GDR task group.

Sequential changes in the GDR task group also included significant improvement in the active range of neck rotation motion, although the control group of diseased subjects without the GDR task did not show such sequential improvement. Furthermore, in a comparison between the groups, the GDR task group revealed significant improvement in the active motion range of neck lateral rotations. The GDR task is responsible for a type of motor imagery. Motor imagery increases muscle contractions [27], enhances body balance in elderly women [28], increases precision of skill and improves motion timing [29], and alleviates post-stroke hemiparesis [30]. In the present study, we determined a significant correlation between reduced reaction times and the enhancement of response accuracy in the GDR task group with improvement of active range of neck motion. However, limited information is available concerning the sequential improvement of active range of motion as a beneficial product of motor imagery [31]. Sequential relief of chronic pain and a negative correlation between VAS pain assessment and active range of motion were observed in the current study, suggesting that reduced pain may be related to improvement of the active range of motion.

Conclusion

In the current study, we investigated GDR effects on neck rotary motion, as well as neck pain in patients with chronic neck pain in the randomized controlled study. In addition, we examined whether such patients had impaired motion simulation of the neck by comparing them with healthy volunteers. As a result, we found that these patients showed prolonged correct RT compared to the healthy volunteer group.

The randomized clinical trial to study effects of the gaze direction recognition task upon cervical rotation and pain in patients with chronic neck pain revealed that a sequence of the tasks increasingly improves the active range of neck rotation and reduces pain. The results suggest that the gaze direction recognition task is a potential therapeutic measure for the treatment of chronic neck pain.

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