■ORIGINAL ARTICLE

Interplay between type-1 diabetes and occupation: Results from a pilot study

Theoretical paper exploring new treatment technique

Venthan J. Mailoo[1], Nick Best[2], Sarah Cheal[3], Francesca Kelly[4], Jeremy Turner[5]

[1] Anaesthetics Senior House Officer, Northampton General Hospital NHS Trust
[2] Locum Occupational Therapist, Day Webster Limited, Unit 103A, Sterling House
[3] Lead Occupational Therapist, Urgent Care Centre and Accident & Emergency, Norfolk Community Health & Care NHS Trust, Norfolk and Norwich University Hospital
[4] Occupational Therapy Team leader – Medicine and Surgery, Norfolk and Norwich University Hospitals NHS Foundation Trust
[5] Consultant Endocrinologist and Honorary Senior Lecturer, Elsie Bertram Diabetes Centre, Norfolk and Norwich University Hospitals NHS Foundation Trust

Abstract: Type-1 diabetes results from cessation of endogenous insulin production. Self-management is essential for patients with type-1 diabetes to prevent secondary organ damage and premature death. Self-management may be inhibited by a vast array of psychosocial factors, and therapy is unlikely to be successful unless these factors are identified and addressed. A pilot study of seven patients from Norfolk in the United Kingdom was undertaken to investigate the psychosocial factors interfering with diabetes self-management. Occupational therapy assessments and interventions were provided in an outpatient clinic. Patients' capacities for diabetes self-management were adversely affected by physical and psychological comorbidities, financial hardship and family responsibilities. Health problems resulting from sub-optimal diabetes self-management included visual impairment, lower limb amputation, erectile dysfunction, hypoglycaemia and diabetic ketoacidosis. A combination of these problems impacted on patients' spiritual lives, interpersonal and intimate relationships, employment prospects, finances and personal power, pleasure and security.

Keywords: Diabetes, NDOSQ, mental-health, self-care

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Introduction

Type-1 diabetes mellitus is usually an autoimmune disease which results in the human body producing no insulin. Insulin is essential to control blood sugar levels. Self-management is usually essential for good outcomes in diabetes [1]. The self-care behaviours required to avoid long-term complications include home glucose monitoring; adjustment of food intake, administration of insulin, foot care and attendance of healthcare appointments [2]. In the long-term, poor diabetes self-management can lead to secondary organ damage such as visual impairment, kidney failure, cardiovascular disease or limb-loss secondary to peripheral neuropathy or infection. Poor self-management of type-1 diabetes can also lead to rapid death from diabetic keto-acidosis (DKA). For most cases of DKA poor adherence to therapy is the likely cause [2]. Qualitative research has shown that patients appreciate advice adapted to suit their individual lifestyles [3], family and economic circumstances [4]. Conversely, when these factors are ignored patients may consider clinicians' advice to be not relevant to them [4]. The prevalence of diabetes among individuals with mental health problems has been estimated as high as double the general population [5]. The prevalence of depression in people with diabetes has been estimated to be between 11% and 32% [6]. It could therefore be argued that consultations should elicit relevant information about how psychosocial factors impact on individual patients and identify mental-health problems in need of treatment. This pilot study was undertaken to determine the nature of psychosocial factors that can be revealed with a one-off holistic occupational therapy consultation.

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Corresponding to: Venthan J. Mailoo, Northampton General Hospital NHS Trust, Cliftonville, Northampton NN1 5BD
e-mail: VenthanMailoo@gmail.com
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Literature Review

Research has shown motivational, patient-centred consultations to be more effective than traditional, didactic approaches for facilitating lifestyle change and improved self-management of diabetes [7]. Hornsten et al. [1] interviewed 44 patients with type-2 diabetes in Sweden and found agreed goals, patient autonomy and feelings of self-worth to be features of satisfying consultations, while disagreement about goals and perception of being forced into submission were features of unsatisfying consultations. Patients wanted non-diabetic factors affecting their lifestyles to be taken into account. 'Patient-centred communication' has been defined as "communicating in a way that conveys sensitivity to the patient's feelings and needs, encourages patient participation, seeks to include the patient's perspective, and attempts to fully inform the patient" [7]. Features of patient-centred practice include a bio-psychosocial perspective, a therapeutic alliance based on sharing responsibility and power and a personal relationship between the patient and clinician [4]. Trust, rapport and communication success are associated with positive therapeutic alliance [8]. Patient-centred care may be patient-led or clinician-led [4]. Qualitative research has indicated that the holistic, patient-centred consultations given by alternative therapists may influence patients to select complementary therapies that lack scientific legitimacy. It has been argued that adoption of these features into conventional healthcare consultations could increase patient concordance [9].

Occupational therapists commonly treat people with organ damage secondary to poorly controlled diabetes [10], such as stroke, visual impairment or limb amputations. It has however been argued that occupational therapy should have a more pro-active, preventative role in facilitating diabetes self-management. Outpatient occupational therapy for diabetes is not a new concept [11]. The American Occupational Therapy Association [12] advocates occupational therapy for exercise, habituation of glucose monitoring, healthy-eating and self-medication, emotional regulation and compensations for secondary organ damage. This has been delivered by direct occupational therapy intervention, sign-posting to community resources [11] and setting up peer-support [13]. As a general trend over time, the focus of published occupational therapy diabetes literature developed from specific, prescribed input based primarily on medical needs, to broader, holistic input incorporating more individualised psychosocial factors. Early articles described multi-disciplinary interventions in which occupational therapists delivered sessions on specified subjects, the most common being exercise [11, 14, 15]. A programme with a much broader remit was described by Scott et al. [16], and was designed to incorporate diabetes management skill-building into everyday functioning; however the extent to which this programme was individually tailored to the user remains unclear.

When psychosocial issues were brought to the fore in more recent studies it was often through the occupational therapy researchers listening to the views of service-users. Hwang, Truax, Claire & Caytap [17] carried out a survey of a mixed type-1 and-2 diabetes population over the age of 55 in the USA. They found that subjects would value assistance in a number of areas which lend themselves to a more holistic, psychosocially-oriented frame of reference such as "improving relationships" and "help with fatigue management and pacing". Interestingly, only 13.7% had ever seen an occupational therapist. Pyatak's [18] qualitative study into young adults with type-1 diabetes produced similar results, with psychosocial issues very prominent in participants' accounts. The young adults interviewed described peer-pressure, social events involving excessive eating or alcohol consumption and concerns about the attitude of others towards insulin injection as major barriers to effective diabetes self-management. Both articles highlighted the potential of occupational therapy's psychosocial frame of reference to help address such issues. The idea that psychosocial interventions are needed in diabetes services, and that occupational therapists are well placed to deliver them, was further developed in a systematic review by Pyatak [19]. The theoretical trend over time towards a less medically prescribed role was identified within the review and the author suggested 'Lifestyle Redesign', an approach developed to address the psychosocial needs of elderly people, as one which could be adapted for use by occupational therapists in a diabetes service. She gave a detailed description of how this was achieved [20], focusing on her attempts to combine the consistency of a manualised intervention with the tailored individualisation of therapy demanded by the differing psychosocial needs of this client group.

The need for psychosocial interventions and the potential for occupational therapy to provide them were also explored by Haltiwanger [13] and Haltiwanger & Brutus [21]. These studies tested peer support overseen by an occupational therapist, in which Mexican-American participants were free to discuss any issues of importance to them. Once again, psychosocial issues were prominent in the concerns raised, including specific discussions of the difficulties diabetic Mexican-Americans had with cultural taboos against refusing food. The results of these preliminary studies suggested that the peer-support group, with its psychosocial focus, was more effective than a health educator-led

group. Overall it appears that psychosocial issues are an important area to address when providing diabetes management interventions, but that this area is often neglected within existing diabetes services. Occupational therapy's biopsychosocial frame of reference may have the potential to address this deficit.

The Norwich Diabetes Occupational Satisfaction Questionnaire (NDOSQ, Appendix 1) was developed from a model first published in the Asian Journal of Occupational Therapy [22] to assess psychosocial factors impairing diabetes self-care and the impact of diabetes on patients' lives from the patients' perspectives. It encourages patients to identify and prioritise their own problems in the following categories: 1. Spiritual, 2. Self-actualisation through psycho-spiritual integration, 3. Expression and communication, 4. Compassion, 5. Personal power and social standing, 6. Hedonism, 7. Basic survival needs. The NDOSQ was used for this research to explore the two-way relationship between type-1 diabetes and occupation.

Research Methodology

Participants

53 patients aged 18 years or over with diabetes mellitus type-1 and adequate mental capacity to consent were invited to take part in this research by their diabetes consultant physician during routine outpatient clinic appointments at the Norfolk & Norwich University Hospital in England. Exclusion criteria were: previous inpatient psychiatric admissions, suspected or confirmed personality disorders and those taking part in other medical research at the time of recruitment. Each patient was given the NDOSQ and the 'Do you want to get the most from life?' leaflet produced by the College of Occupational Therapists [23] while the consultant explained that the research was to explore the potential for occupational therapy to improve quality of life for patients with type-1 diabetes. Patients were contacted by telephone at least 24 hours later, and asked whether they would like to take part in the research. Eight patients (5 males and 3 females aged 39−71) consented and were invited to outpatient occupational therapy appointments. One of these did not attend his occupational therapy appointment. Patients are identified by sex (M/F) and age in years only (M40, M55, M56, M63, F39, F59, F71) to preserve anonymity.

- F39 previously managed a career in healthcare despite problems with alcoholism. She later developed diabetes and was unable to continue work due to frequent emergency hospital admissions for DKA, compounded by agoraphobia. She lived alone but received some support from a substance-abuse mental health team.
- F59 was a healthcare professional, married with children. She had successfully managed her diabetes, and so had no significant secondary organ damage. She had caring responsibilities for family members with physical and mental health problems.
- F71 had retired, but had also successfully managed her diabetes, so her career had not been affected and she had no significant secondary organ damage.
- M40 was married. He was unable to work due to several health problems and was being treated with anti-depressant medication.
- M55 was previously a lorry driver but was unable to work due to complications of diabetes. He had a below-knee amputation and presented at the occupational therapy interview with a new ulcer on his amputation stump.
- M56 was in the process of divorce, socially isolated and unable to work due to multiple health problems including generalised musculoskeletal pain. He had visual impairment likely to be secondary to poor glycemic control and cognitive impairments that may have been due to pseudo-dementia secondary to anxiety and depression, or micro-vascular disease secondary to poor glycaemic control.
- M63 had attended grammar school as a child but was distracted from his education by the diagnosis of diabetes. He was married and cared for his children who had multiple disabilities. Due to successful diabetes management he had no significant secondary organ damage.

Materials

Structured interviews based on the NDOSQ were conducted in the General Medical Outpatients Department of the Norfolk & Norwich University Hospital.

Procedure and Data analysis

Patients were asked to think about and complete the NDOSQ before attending their occupational therapy appointment. They were then assessed by an occupational therapist in a 45-minute outpatient clinic appointment during which any issues the patients raised on the NDOSQ were discussed. Three different occupational therapists took part in this study but each patient was seen by only one occupational therapist. The occupational therapists offered practical advice and signposting or referrals for appropriate follow-up. Patients' responses to the NDOSQ and issues raised during the occupational therapy appointments were analysed for themes. This pilot study was approved by the South Central - Berkshire Research Ethics Committee in accordance with the ethical standards of the Helsinki Declaration.

Results and discussion

Spiritual domain

The NDOSQ is based on the assumption that spirituality is the core of being, on which everything else is constructed. Spiritual awareness is therefore assessed with the question "What is the most important thing to you in your life?" For most people, success in this domain is thought to depend on opportunities for altruistic actions that contribute to a sense of self-worth [22]. For people with antisocial personality disorder altruism may not be required for spiritual fulfilment, but people with personality disorder were excluded from this research. Capacity for altruistic action may depend on either self-sacrifice or success in the other domains. Of the 7 patients who took part in this pilot study only two identified altruism as the most important thing in their lives:

- F59's career was based on altruism. The most important things to her were "being able to care for" her relatives with a stroke and mental health problems, while also staying in work. Diabetes had minimal or no impact on her occupational freedom. She stated however that the demands placed on her by her caring and work responsibilities made her vulnerable to hypoglycaemia.
- M63 stated his "wife and two children" were most important in his life. His children had "multiple disabilities" and his "diabetic control requirements" impaired his ability to care for them. "Sometimes my requirements take second place".

Of the other 5 patients, one (F71) identified mindfulness as the most important thing in her life. This suggests a high capacity for psycho-spiritual integration. The other patients indicated that basic survival needs were most important. This reflects limited opportunities or capacity for spiritual fulfilment. Occupational therapy intervention for basic health and social needs may be necessary before altruism can be addressed.

Psycho-spiritual integration

This domain depends on self-actualisation despite social pressures that may discourage individuals from living spiritually authentic lives. The NDOSQ assesses this by asking "How is diabetes affecting your ambitions or goals?" This question is based on the assumption that people may not pursue their inner-callings due to fears or low expectations. F59, F71, M55 and M63 expressed no problems with this domain though M63 wondered whether his life ambitions would have been different if he did not have diabetes. F71 stated "Living the day" was the most important thing in her life, reflecting an attitude of mindfulness conducive to psycho-spiritual integration. This mindfulness had not however been mastered and F71 expressed uncertainties about the future, indicating that she was worried that she would not be able to manage her diabetes if she acquired cognitive impairments in the future. The other three patients' capacities for self-actualisation were limited by more basic unfulfilled health or social needs.

- M40: "For over 40 years none with other health issues, not being able to achieve"
- M56: "Internet cut off. OU degree cancelled. No ambitions."
- F39: "was high functioning initially despite alcoholism. Diabetes threw this balancing act"

Occupational therapy interventions for basic health and social needs, facilitated goal-planning or vocational rehabilitation could be useful for psycho-spiritual integration.

Expression and communication

Self-expression is assessed in the NDOSQ by the question "In life generally, do you feel able to express yourself and have your questions answered?" F39 described herself as "quite British and quite reserved" even when she became angry. This behavioural trait has been associated with poorer prognosis for patients with autoimmune diseases [24]. F39 complained that occasionally as an inpatient she thought the insulin doses she was being given were too high, but healthcare staff did not listen to her and she subsequently became hypoglycaemic. "I do not need a nurse telling me what to do." This disempowering alienation may have been secondary to judgements made by clinical staff based on the frequency of F39's DKA recurrences. F39 explained that DKA only occurred when her mental capacity was impaired by intoxication secondary to alcoholism, and she felt capable of self-care following detoxification in hospital. M56 believed that "people do not have the time" to listen to him. Use of the NDOSQ followed up by group occupational therapy may be a good start at addressing the alienation experienced by these patients.

Compassion

The NDOSQ assesses this domain with the question "How is diabetes affecting your relationships?" Two patients (F39 and M63) said that aggressive behaviour secondary to hypoglycaemia impaired their relationships with other people such as family or healthcare staff. F59 stated her "husband gets annoyed by" her hypoglycaemic episodes if they are frequent, and expressed getting "stressed with juggling everything trying to keep everyone happy." One patient's intimate relationship had previously been affected by erectile dysfunction, but this had been remedied with a vacuum pump. M40 attended

with his wife. They both described how recent deteriorations of his physical health had emotionally strained them both despite a strong, loving relationship. M40 reported tearfulness and "being snappy at times" despite being treated with anti-depressant medication. M56 was "half-way through a divorce." This may have been precipitated by his diabetes and multiple co-morbidities straining his relationship, but the stress of divorce was also impairing his diabetes self-care due to maladaptive coping strategies. Occupational therapy interventions to increase social support could reduce the strain on these patients' personal relationships.

Personal Power

The NDOSQ uses career success as a crude measure of personal power and social standing. This is not an acute measure, as materially successful people can suffer acute losses of personal power during acute illness. F39 for example, felt that control was taken away from her during hospital admissions and "a patient should be allowed to manage" their own diabetes "if they have capacity." Similarly M55 was trying to manage a painless pressure sore on his amputation stump himself without seeking medical attention. When the occupational therapist spotted this she referred him to the consultant physician for immediate review, who then referred him to a podiatrist for tissue viability care to prevent further limb loss. M55 expressed dissatisfaction with his autonomy being disrespected and described this intervention as "cheeky". These examples of patients prioritising sense of personal power over diligent management of basic survival needs may be considered by healthcare professionals to be maladaptive behaviour. F39, M40 and M56 felt unable to work due to co-morbidities. F39 was worried she would be discriminated against due to diabetes and M40 stated "I feel that I have to prove I can do more than others to be the same." M56 said he had "no career prospects" and was "unable to work." These patients generally fared worst in all domains of the NDOSQ. Other patients had varying degrees of success. M55 felt that his mobility affected his glycaemic control. "I lost my class 1 heavy goods vehicle licence but do my best to stay in work." M63 described himself as a successful grammar school student who lost his sense of ambition when he was diagnosed with diabetes. He wondered how his life may have differed if he had not developed diabetes in his youth. F59 said that hypoglycaemia occasionally affected her at work, but this had not affected her career. F71 believed that due to adjusting well to her diagnosis, her career had not been significantly affected. Occupational therapy for vocational rehabilitation or patient advocacy by occupational therapists could be used to reduce patient disempowerment.

Hedonism

Patients whose basic survival needs had been fulfilled were generally able to seek pleasure. Conversely F39 reported inability to have fun due to agoraphobia and alcoholism. M63 wanted to go abroad on holiday but was afraid to do so because of his diabetes, and therefore had not travelled. If younger patients had been recruited into the sample greater adverse effects of pleasure-seeking on diabetes self-care may have been revealed by the data. Speaking of his youth M63 said:

"Yeah it does stop you having fun … all your mates used to go out drinking, so you would as well, feel rough for a few days after but"

M56 reported frequently binge-drinking alcohol and consuming sugary foods as maladaptive coping strategies to deal with the stress of divorce and financial insecurity. These behaviours are likely to lead to secondary organ damage. M56 also stated "I don't have fun." F59 reported that what she most wanted was leisure time with her husband, but that caring for her relatives and her own diabetes management made this "impossible". The occupational therapist signposted her to carers' support and sources of funding for hired carers. Patients may benefit from occupational therapy to introduce less-harmful pleasurable behaviours and peer-supported group recreational activities.

Basic survival needs

Poorly controlled diabetes is a direct threat to survival. F71 had attended a Dose Adjustment For Normal Eating diabetes self-management course and was happy with her diabetes self-management at present despite feelings of insecurity regarding the future. She expressed clear indicators of success in every domain of the NDOSQ except spirituality. This specific deficit may reflect a weakness of the NDOSQ rather than an absence of spiritual awareness in the patient's life. In contrast, the patients who expressed deficits in multiple other domains expressed underlying problems in this one. M63 felt he and his wife needed a "well overdue break" from taking care for their disabled children. Rest is a basic survival need; not a pleasure-seeking need. M40 worried about financial insecurity because both he and his wife were not working due to long-term illness. He said his resulting stress levels negatively impacted on his diabetes self-management. M56 stated he had "no money", "stress", a "bad diet" and fears about an undiagnosed cognitive impairment and said "I only feel safe when my mates pop in." His function was also limited by chronic musculoskeletal pain, visual and cognitive impairment. All of these factors adversely impacted on his ability to attend to diabetes self-management. This patient would

benefit from further occupational therapy for in-depth cognitive testing and medical screening for dementia. He was therefore referred to community occupational therapy and his general medical practitioner.

M55 already had a below-knee amputation secondary to poor glycaemic control. His reluctance to report a new stump ulcer to medical staff put him at risk of further limb loss. Of all 7 patients, F39 had the most admissions for DKA and was at greatest risk of sudden loss of life due to poor diabetes self-management. F39 had not been seen by an occupational therapist before and was dissatisfied by her perceived lack of psychological support for alcoholism provided by the local substance misuse service. She was initially obsessive about glycaemic control and set an alarm to check her blood glucose level every 2 hours. This resulted in sleep disturbance. She described becoming "nonchalant" later in her disease course though she experiences continual anxiety regarding possible secondary organ damage such as blindness or amputation of her feet. Threats to F39's basic survival had overwhelmed her to the extent that she is no longer able to pursue success in any of the other domains. F39 could benefit from intensive community occupational therapy to connect her with coping resources to fill every domain of the NDOSQ in addition to ongoing support from substance misuse services and psychiatric support for agoraphobia. Diabetes can also complicate the treatments of other medical problems. M63 for example said: "I had a hydrocortisone injection in my shoulder and it really did scupper me for a few days."

This pilot study was limited by a small sample size of self-selected patients. It is possible that only the concordant patients with psychosocial problems would consent to an extra hospital appointment to try occupational therapy. It is important to gather data from patients who are non-concordant with diabetes care and do not attend their clinic appointments. No younger patients consented to take part in this research. It is possible that the hedonistic behaviours of teenage patients may increase their risk of DKA or secondary organ damage. It would therefore be useful to repeat this research with inpatients admitted to hospital with DKA. The NDOSQ is a crude, un-validated tool and cannot be used as a substitute for in-depth holistic occupational therapy interviews.

Summary and Conclusions

This small pilot study of 7 patients confirmed that type-1 diabetes can impact on patients' self-awareness, interpersonal relationships, employment and career prospects, sense of autonomy and social standing, enjoyment, sexual function, mental health, physical health and sense of security. The patients' responses also confirmed that co-morbidities, financial factors, pleasure-seeking and interpersonal relationships all impact on patients' capacities for diabetes self-care. Many of these problems were occupationally mediated. Unless patients are provided with holistic treatment plans to help them manage their life problems, diabetes management is unlikely to be optimal. This pilot study has therefore revealed a role for occupational therapy in diabetes out-patient clinics.

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Appendix 1

Norwich Diabetes Occupational Satisfaction Questionnaire (Version 1)

How is diabetes affecting your life, and what can we do about it? Occupational therapy is to help people live happy, healthy lives. Please think about these questions while waiting for your appointment and write down any issues you would like to discuss. It may not be possible to discuss everything in one appointment, so the issues most important to you will be discussed first. Continue writing on the back of this page if necessary.

Life area	**Problems**	Please allocate these problems an **order of priority** to show how important they are to you. The most important problem should be numbered '1' with less important problems given higher numbers '2, 3, 4' etc.
What is the most important thing to you in your life? a) How is diabetes affecting this issue? b) How does this issue affect your diabetes?		
How is diabetes affecting your ambitions or goals? How are your ambitions and goals affecting your diabetes?		
In life generally, do you feel able to express yourself and have your questions answered?		
How is diabetes affecting your relationships? How are your relationships affecting your diabetes?		
How is diabetes affecting your career prospects? How does your career impact on your diabetes?		
How is diabetes affecting your opportunities to have fun? How are fun activities impacting on your diabetes?		
Do you feel safe? How does this affect your diabetes? How does your diabetes affect this?		

■ORIGINAL ARTICLE

Do presentation modality and cognitive load affect standing stability?

Yoko Kimura[1], Shinji Satake[2], Hiromi Fujii[2], Takaki Kafuku[3], Miyuki Fujikura[3]

[1] Department of Occupational Therapy, Tohoku Medical College, Hachinohe, Japan
[2] Department of Occupational Therapy, Yamagata Prefectural University of Health Sciences, and the Area of Occupational Therapy, Graduate School of Health Sciences, Yamagata Prefectural University of Health Sciences, Yamagata, Japan
[3] Department of Occupational Therapy, Tohoku Medical College, Hachinohe, Japan

Abstract: There are some brain disease sufferers, who face difficulties in performing various tasks while maintaining standing posture. We examined how the difference in presentation modality and cognitive load affect information processing and the maintenance of standing posture. We assigned tasks based on the Paced Serial Addition Test (PSAT) to 11 healthy adults. More precisely, we presented digits auditorily or visually and analysed parameters, namely, the precision and the speed of processing as well as the center of pressure (COP). It was found that both the precision and the speed of processing were higher in visual presentation than in auditory presentation, and as cognitive load increased these parameters began to show poorer results. COP became unstable when cognitive load exceeded a certain degree.

Keywords: modality, cognitive load, information processing, standing posture

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1. Introduction

In our daily lives we perform various tasks while standing. For example, we talk, watch or think while simultaneously maintaining standing posture. Unlike healthy people, however, there are patients who face certain difficulties in such task performance due to cerebrovascular disease, schizophrenia or other brain diseases. As long as they concentrate only on maintaining standing posture, the posture remains stable. When others talk or show something to them, however, the posture may become unstable and conversation or thinking process could be interrupted. In human actions, a series of information processing from receiving external information through various sensory organs, cognizing it to choosing adaptive movements is carried out for various tasks at a time.

It has been reported that many factors such as age [1, 2], visual information [3], auditory information [4], mental arithmetic [5] and recognition tasks [2, 4, 6] affected standing posture. But the influence of the difference in presentation modality or in cognitive load has never been documented.

It is generally believed that humans collect 80% of external information visually and 10% auditorily. In addition, there are reports that auditory sense is superior to vision with regard to sensory memory duration and simple reaction time [7−9]. In other words, the difference in presentation modality may have a certain kind of influence on subsequent information processing and task performance. Moreover, it is said that information processing depends heavily on the capacity of working memory [10−12]. It is likely that when we have brain disease, the sensory input mode shifts and working memory load increases, hence changes in information processing and standing posture.

Elucidation of such influence may enable us to develop an assessment battery for examining one's ability to perform tasks and maintain standing posture at a time. In addition, it may suggest appropriate ways of presenting information which allow one to think and perform tasks while safely maintaining standing posture. Therefore, the purpose of this study is to clarify the influence of the difference in presentation modality and in cognitive load on information processing and standing posture with the use of parameters: processing precision, processing speed and the center of pressure (COP).

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Corresponding to: Yoko Kimura, Tohoku Medical College, 3-6, Nashirozawa, Gonohe, Sannohe, Aomori, 039-1522, Japan
e-mail: ichikawa-kim@rinken.ac.jp
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2. Material and methods

2.1. Participants

Participants were 11 healthy adults (gender: male 6, female 5, age: 23 ± 4 years, height: 168.09 ± 11.46 cm, weight: 59.82 ± 10.82 kg) with no hearing impairments and visual acuity of 1.0 (measured by the Landolt C). All of them were right-handed and had never received the Japanese abacus training. They were able to stand still while adjusting the initial COP to the base point of the force plates. People with disorders or problems which could affect standing posture or mental arithmetic were not included. This study was approved by the ethics committees of Yamagata Prefectural University of Health Sciences and Tohoku Medical College and all participants agreed to join, having been given due explanation about the purpose of this study prior to the experiment.

2.2. Tasks and Procedures

Tasks were derived from the Paced Serial Addition Test, or PSAT [13], which required that participants should be presented with 61 single digits in random order and quickly add each new digit to the one immediately prior to it. PSAT is a measure of attention deficit and has two types, both of which were applied for this study. One is the Paced Auditory Serial Addition Test, or PASAT [14], where digits are presented auditorily and the other is the Paced Visual Serial Addition Test, or PVSAT [15], where digits are presented visually.

Four types of cognitive load were provided in the form of N-back tasks [16] for PASAT and PVSAT respectively. The tasks were adding each new digit to the digit immediately before it (1-back), to the digit two previous to it (2-back), to the digit three previous to it (3-back) or just repeating each new digit (0-back). Participants were asked to answer (the range of correct values: 3−17) or repeat (the range of correct values: 1−9) as quickly as possible while maintaining static standing posture.

Although 61 single digits were presented randomly, the same digit was never presented consecutively. The interval between two digits was 3.0 seconds both in PASAT and in PVSAT just as it was in PSAT. The duration of digit presentation was about 0.5 seconds, i.e., the time length for an auditorily presented digit to sound natural enough, and in PASAT the average time from the beginning of the first syllable of a digit until the beginning of the last was 0.288 seconds. Arabic numerals were used in PVSAT. Tasks were provided in a random manner in order to avoid the effect of memory, and the duration of each task was planned not to exceed three minutes to prevent fatigue. There was a break between tasks, and the experiment was resumed only after confirming that participants were feeling no fatigue. Fig. 1 illustrates these tasks and procedures.

2.3. Participants' Posture and Device Setting

2.3.1. Participants' posture

As in Romberg' test, participants were requested to stand barefoot on force plates placed in a dim room [5], letting arms hang down naturally (Fig. 2).

2.3.2. Device setting

In PASAT digits were presented at the right volume through earphones connected to a PC. In PVSAT digits were presented on a screen set in front of the participant through a projector connected to a PC. The position of digits was adjusted to the eye level of each participant. Digits were presented in 1.7 degrees of visual angle so

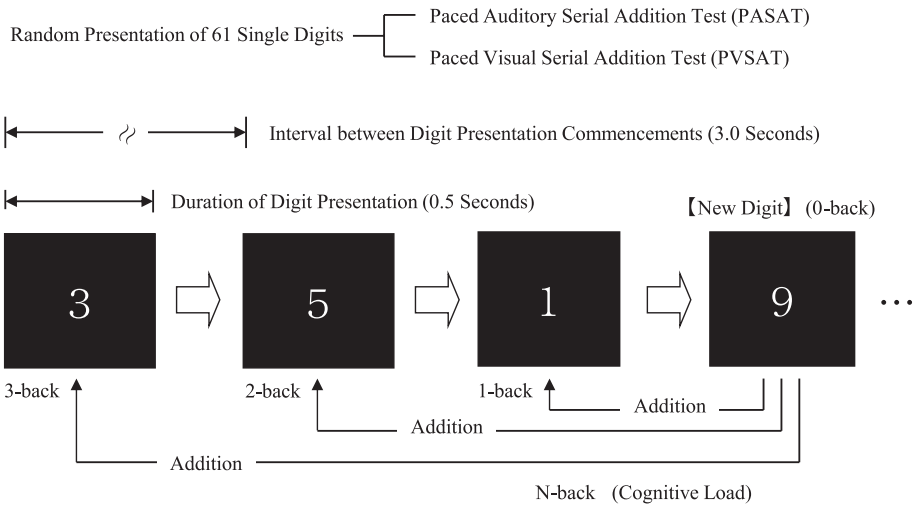

Fig. 1. PASAT/PVSAT Administrative Conditions.

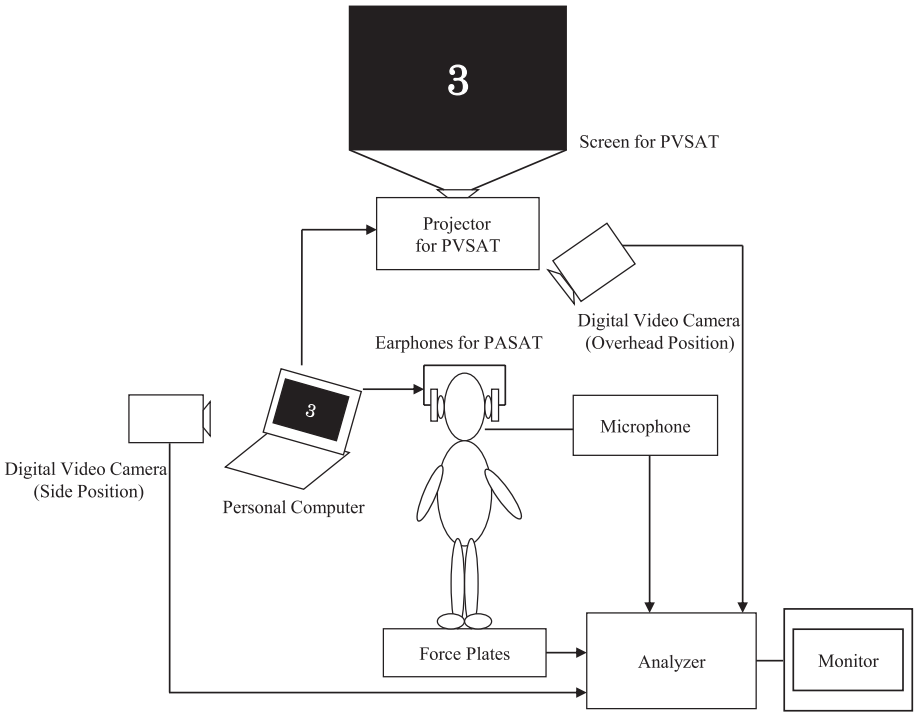

Fig. 2. Participants' Posture and Device Setting.

that they were large enough for any participant to fully identify. Participants were requested to keep opening their eyes during tasks. In PASAT, they were also requested to watch on the same height point on the wall as digits presented in PVSAT. Throughout the task performance COP was recorded at the sampling frequency of 50Hz using two force plates (Kineto Gravicorder G-7100 manufactured by Anima Corp., Tokyo, Japan). In order to distinguish correct answers and incorrect ones, presented digits (sounds or images) and participants' oral answers were recorded with two digital video cameras (NV-GS300 manufactured by Panasonic Corp., Osaka, Japan: 30 frames per second) placed in the participant's overhead and side positions respectively. In addition, in order to measure reaction time, oral answers were recorded at the sampling frequency of 2,000Hz with a microphone (ECM-TL1 manufactured by Sony Corp., Tokyo, Japan) connected to a PC. At the same time, the whole data, namely, COP, presented sounds/images and participants' oral answers, were recorded with a real-time synchronous recording system for digital motion pictures and waveforms (Teraview manufactured by Gigatex Co. Ltd., Osaki, Japan).

2.4. Analysis

2.4.1 Analyzed items

<Processing Precision>

Processing precision was quantified in the form of the percentage of correct answers for all tasks (60 answers) both in PASAT and in PVSAT.

<Processing Speed>

Processing speed was quantified in the form of reaction time both in PASAT and in PVSAT. For every answer in each task (60 questions), the time from the beginning of the digit presentation until the beginning of the answer was measured.

<Instability of Standing Posture>

For each task the distance COP travelled during the time from the beginning of the first digit presentation until the end of the last (60th) answer was measured. Instability of standing position was quantified in the form of that distance divided by the time consumed (mm/s).

2.4.2. Comparison of items

In order to identify the influence of the difference in presentation modality on information processing and the maintenance of standing posture, we compared the percentage of correct answers, reaction time and travel distance of COP between the tasks of PASAT and PVSAT sharing the same N.

Also, in order to identify the influence of the difference in cognitive load on information processing and the maintenance of standing posture, we compared the same items as above between the tasks with different Ns both in PASAT and in PVSAT.

For the purpose of statistical data treatment the Wilcoxon signed-rank test was used and the level of significance was set at less than 5%.

3. Results

The percentage of correct answers, reaction time and travel distance of COP are shown in Table 1.

3.1. Influence of Difference in Presentation Modality on Information Processing and Maintenance of Standing Posture (Table 2)

<Processing Precision>

In 0-back tasks no significant difference was found in the percentage of correct answers between PASAT and PVSAT.

In 1-back, 2-back and 3-back tasks the percentage of correct answers of PVSAT was significantly higher than that of PASAT ($p < .01$, $p < .05$ and $p < .05$, respectively).

<Processing Speed>

In 0-back, 1-back, 2-back and 3-back tasks, reaction time of PVSAT was significantly shorter than that of PASAT ($p < .01$, $p < .05$, $p < .01$ and $p < .01$, respectively).

<Instability of Standing Posture>

No significant difference was found in travel distance of COP between PASAT and PVSAT.

3.2. Influence of Difference in Cognitive Load on Information Processing and Maintenance of Standing Posture (Table 3)

<Processing Precision>

The percentage of correct answers decreased as cognitive load increased, and a significant difference was found whenever two tasks with different Ns were compared both in PASAT and in PVSAT ($p < .01$ and $p < .01$, respectively).

<Processing Speed>

In PASAT reaction time became longer as cognitive load increased, and a significant difference was found whenever two tasks with different Ns were compared ($p < .05$ or $p < .01$).

In PVSAT reaction time became longer as cognitive load increased, and a significant difference was found between 0-back and 1-back tasks ($p < .01$), between 0-back and 2-back tasks ($p < .01$), between 0-back and 3-back tasks ($p < .01$), between 1-back and 3-back tasks ($p < .01$) and between 2-back and 3-back tasks ($p < .05$). However, no significant difference was found between 1-back and 2-back tasks.

<Instability of Standing Posture>

In PASAT travel distance of COP became longer as cognitive load increased, and a significant difference was found between 0-back and 3-back tasks ($p < .05$) and between 1-back and 3-back tasks ($p < .05$). No significant difference was found in other combinations of tasks.

In PVSAT travel distance of COP became longer as cognitive load increased, and a significant difference was found between 1-back and 2-back tasks ($p < .05$) and between 1-back and 3-back tasks ($p < .01$). No significant difference was found in other combinations of tasks.

4. Discussion

Data Summary is shown in Table 4.

Table 1. Percentage of Correct Answers, Reaction Time and Travel Distance of COP.

		PASAT	PVSAT
Percentage of Correct Answers (%)	0-back	100	100
	1-back	88 (65−100)	93 (85−100)
	2-back	48 (42−93)	72 (42−85)
	3-back	37 (18−55)	47 (25−70)
Reaction Time (s)	0-back	1.07 (0.936−1.26)	0.593 (0.535−1.34)
	1-back	1.27 (1.17−1.47)	1.05 (0.801−1.50)
	2-back	1.46 (1.13−2.04)	1.16 (0.819−1.80)
	3-back	1.90 (1.35−2.29)	1.41 (1.01−1.88)
Travel Distance of COP (mm/s)	0-back	11.9 (7.1−16.1)	11.3 (7.5−15.6)
	1-back	11.5 (6.6−17.4)	9.8 (6.5−19.4)
	2-back	12.7 (7.6−23.4)	12.4 (5.8−19.6)
	3-back	14.2 (6.7−23.4)	12.4 (7.0−21.7)

Note. N = 11.
Median (Minimum – Maximum)

Table 2. Influence of Difference in Presentation Modality on Information Processing and Maintenance of Static Standing Posture.

		PASAT	PVSAT
Percentage of Correct Answers	0-back	−	n.s.
	1-back	<	**
	2-back	<	*
	3-back	<	*
Reaction Time	0-back	>	**
	1-back	>	*
	2-back	>	**
	3-back	>	**
Travel Distance of COP	0-back	−	n.s.
	1-back	−	n.s.
	2-back	−	n.s.
	3-back	−	n.s.

Note. N = 11.
*$p < .05$. **$p < .01$.

Table 3. Influence of Difference in Cognitive Load on Information Processing and Maintenance of Static Standing Posture.

	PASAT				PVSAT			
Percentage of Correct Answers	0-back	>	1-back	**	0-back	>	1-back	**
	0-back	>	2-back	**	0-back	>	2-back	**
	0-back	>	3-back	**	0-back	>	3-back	**
	1-back	>	2-back	**	1-back	>	2-back	**
	1-back	>	3-back	**	1-back	>	3-back	**
	2-back	>	3-back	**	2-back	>	3-back	**
Reaction Time	0-back	<	1-back	**	0-back	<	1-back	**
	0-back	<	2-back	**	0-back	<	2-back	**
	0-back	<	3-back	**	0-back	<	3-back	**
	1-back	<	2-back	*	1-back	-	2-back	n.s.
	1-back	<	3-back	**	1-back	<	3-back	**
	2-back	<	3-back	*	2-back	<	3-back	*
Travel Distance of COP	0-back	-	1-back	n.s.	0-back	-	1-back	n.s.
	0-back	-	2-back	n.s.	0-back	-	2-back	n.s.
	0-back	<	3-back	*	0-back	-	3-back	n.s.
	1-back	-	2-back	n.s.	1-back	<	2-back	*
	1-back	<	3-back	*	1-back	<	3-back	**
	2-back	-	3-back	n.s.	2-back	-	3-back	n.s.

Note. N = 11.
*p < .05. **p < .01.

Table 4. Data Summary.

	Influence of Difference in Presentation Modality on Information Processing and Maintenance of Static Standing Posture		Influence of Difference in Cognitive Load on Information Processing and Maintenance of Static Standing Posture	
	PASAT	PVSAT	Small Load	Large Load
Percentage of Correct Answers	Lower	Higher	Higher	Lower
Reaction Time	Longer	Shorter	Shorter	Longer
Travel Distance of COP	No Difference		Shortest in 1-back Task	Longest in 3-back Task

4.1. Influence of Difference in Presentation Modality on Information Processing and Maintenance of Standing Posture

Processing precision, namely, the percentage of correct answers, was higher in PVSAT than in PASAT when N, the indicator of cognitive load, was more than 0. As for processing speed, reaction time was longer in PASAT than in PVSAT regardless of the value of N.

Past literatures on mental arithmetic reported that cognitive load was smaller in visual presentation than in auditory presentation [17], and that the same part of the cerebrum was active whether the presentation was auditory or visual [18]. Thus it is suggested that mental arithmetic depends conclusively on visual images. In other words, addition of visually-presented numbers may be actually performed in two steps, namely, recognition of Arabic numerals and following practical calculation, whereas addition of auditory stimuli may need three steps, namely, phonological identification, recollection of Arabic numerals and practical calculation.

Considering the above, it is presumed that the results of PASAT in processing precision and speed were inferior to those of PVSAT because its intricate procedure preceding practical calculation became an extra burden and interfered with the maintenance of auditory information. That burden, however, may not be heavy enough to disturb the maintenance of standing posture, as no difference was found between PASAT and PVSAT in travel distance of COP.

4.2. Influence of Difference in Cognitive Load on Information Processing and Maintenance of Standing Posture

Both in PASAT and in PVSAT the percentage of correct answers, i.e. the indicator of processing precision, decreased and reaction time, i.e. the indicator of processing speed, became longer as cognitive load increased. This result suggests that the increase of cognitive load imposed on working memory affects a serial process from perception, cognition, encoding, maintenance, recollection to mental arithmetic, only to complicate information processing.

Both in PASAT and in PVSAT again, travel distance of COP, the indicator of instability of standing posture, became long when N, the indicator of cognitive load, reached 3. This result may be related to the distribution of attention which happens in the dual-task situation where one is asked to perform information processing and to maintain standing posture simultaneously. It is likely that in daily activities one divides his/her attention which is supposed to be a limited processing potential. Therefore, the more attention one task attracts, the less attention the other is allocated, which induces the latter's poor performance.

Considering the above, it may safely be said that this study suggests that the increase of cognitive load imposed on working memory boosts attention to PASAT/PVSAT while reducing attention to the maintenance of standing posture. Standing posture seems to become unstable especially in 3-back tasks. 0-back tasks include the load of just one digit, which can be regarded as one chunk of memory [19, 20]. Then, working memory load in 3-back tasks, where one is requested to remember at least 4 digits while performing addition, may be equivalent to more than 4 chunks of memory. Therefore, it is suggested that even a healthy person's standing posture may become unstable when he/she is given more than 3 units of information, regardless of presentation modality, and, on top of it, the necessity of relevant mental operations.

5. Conclusion

This study suggested that visual presentation of information was more effective than auditory presentation in maintaining the precision and the speed of task performance while standing. It also indicated that no more than 3 chunks of information should be presented, whether auditorily or visually, in order to prevent postural instability.

Because of the limitaiton that the participants were only healthy adults in this study, a certain consideration should be given when adapting these findings to patients with brain diseases. The number and the time of tasks might burden patients if this method is simply applied in a clinic. Therefore, further research will be needed to simplify the method to make it applicable to patients with brain diseases.

6. Appendices

Figure1: PASAT/PVSAT Administrative Conditions
Figure2: Device Setting
Table1: Percentage of Correct Answers, Reaction Time and Travel Distance of COP
Table2: Influence of Difference in Presentation Modality on Information Processing and Maintenance of Static Standing Posture
Table3: Influence of Difference in Cognitive Load on Information Processing and Maintenance of Static Standing Posture
Table4: Data Summary

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■ORIGINAL ARTICLE

Differences between older and younger drivers in a Japanese road sign recognition task

Tsutomu Sasaki[1, 2], Kyohei Yamada[1], Takao Kojima[3], Kunihiro Kanaya[4], Kazuki Umeda[5], Yusuke Nakajima[6]

[1] Hokkaido Chitose Institute of Rehabilitation Technology, Chitose, Japan
[2] Division of Occupational therapy, School of Health Sciences, Faculty of Medicine, Shinshu University, Matsumoto, Japan
[3] Department of Rehabilitation, Shuyukai Hospital, Sapporo, Japan
[4] Department of Rehabilitation Medicine, Sasson-Sugata Clinic, Otaru, Japan
[5] Department of Rehabilitation, Aizawa Hospital, Matsumoto, Japan
[6] Department of Rehabilitation, Shinano-Iryo Fukushi Center, Shimosuwa, Japan

Abstract: Recent years, cases in which an occupational therapist is involved in the evaluation of patients' driving ability are rapidly increasing in Japan. One of the neuropsychological tests which are predictive of driving ability is a road sign recognition task (RSR). However, no RSR available in Japan has yet been reported. Hence, in this study, we developed a Japanese version of road sign recognition task (J-RSR). A total of 44 younger drivers and 43 older drivers living in the community took part in the study. We compared the number of correct answers and the total time taken to complete the task between the two groups. Results showed that there was no statistically significant differences for the number of correct answer ($p = 0.43$), while older drivers took significantly much longer than younger drivers to complete the task ($p < 0.000001$). Qualitative analysis on incorrect answer for each question revealed that older drivers chose the same incorrect road sign answer while younger drivers chose incorrect answer evenly among options. These results suggest that J-RSR is predictive of knowledge of road sign, non-verbal reasoning ability, mental speed, and might reflects subjects' driving experience.

Keywords: driving, assessment, road sign recognition task

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Introduction

It is estimated that about 65% of the Japanese population currently has an ordinary motor vehicle license (i.e., driver's license) [1]. Indeed, for many, cars are an indispensable means of transport in daily life. If individuals are deprived of the use of their cars due to disability, their quality of life can significantly decrease [2]. Therefore, it is very important to evaluate disabled subjects' driving ability while they are hospitalized. Cases in which an occupational therapist is involved in the evaluation of patients' driving ability are rapidly increasing at medical institutions that deal with stroke and dementia patients in Japan.

One aspect of driving ability evaluations carried out at medical institutions is the neuropsychological evaluation. This evaluation assesses whether an individual has the necessary cognitive functions required to drive a car, and often includes a visual search task [3−5], reaction time task [6−8], visuo-spatial recognition task [9−11], useful field of view test [12, 13], and intelligence test [14−16]. However, these tests have a shortcoming in that they do not use actual driving scenes in their assessments. This, in turn, leads to clinical problems such as lack of agreement between patients and occupational therapists on whether the test results reflect patients' actual driving ability.

One test, called the Stroke Driving Screening Assessment (SDSA), has been developed specifically for the evaluation of driving ability [17]. The SDSA is widely used for predicting the results of on-road evaluations [18−21]. The SDSA comprises four tasks: dot cancellation, compass, square matrix, and the road sign

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Corresponding to: Tsutomu Sasaki, Division of Occupational therapy, School of Health Sciences, Faculty of Medicine, Shinshu University, 3-1-1, Asahi, Matsumoto, Nagano, 390-8621, Japan
e-mail: t-sasaki@chitose-reha.ac.jp
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recognition test (RSR). Dot cancellation is used as an indicator of visual attention function, while the square matrix and compass are used as indicators of the ability to identify orientation and the RSR as an indicator of knowledge of road signs. The result of each sub-test correlates with the result of an on-road evaluation [20−23].

Among these sub-tests, we are most interested in the RSR, which is more closely related to actual driving. The test requires the patient to identify the road sign appropriate for a given road situation. Passing this test requires both knowledge of road signs and non-verbal reasoning ability [24−25]. However, in all cases reported to date, drawings of road signs and road situations have been used instead of photographs. In addition, because road signs and traffic regulations differ by country, tests developed in a foreign country cannot be used in Japan. We have therefore developed the Japanese version of the RSR (J-RSR) using photographs to present the road situations. In this study, we report the results of an analysis of the characteristics of older and younger driver's license holders.

Methods

Participants

A total of 44 younger driver's license holders (17 male drivers and 27 female drivers; age: 22.0 ± 2.9 years old) and 43 older driver's license holders (22 male drivers and 21 female drivers; age: 68.0 ± 6.0 years old) living in the local community took part in the study. The average score of the Mini-Mental State Examination (MMSE) of the older driver's license holders was 28.7 ± 1.4. Among younger driver's license holders, 5 obtained their licenses less than a year ago, 13 obtained them between one and two years ago, 12 obtained them between two and three years ago, 11 obtained them between three and four years ago, and 3 obtained them more than three years ago. In terms of driving frequency, 2 were driving daily, 4 were driving once every 2 or 3 days, 6 were driving once a week, 15 were driving a few times a year, and 17 hardly drove. Among the older driver's license holders, 32 had obtained their licenses more than forty years ago, 2 each had obtained them between 10 and 20 years ago and between 20 and 30 years ago, and 7 had obtained them between 30 and 40 years ago. All participants received an explanation of the study verbally and in writing and gave consent. The study was carried out upon obtaining approval from the Medical Research Ethics Committee of Shinshu University (approval number: 2081)

Tasks and procedures

The participants took the J-RSR and the Trail Making Test (TMT) using a touch-screen notebook computer (CF-C1B 12.1"; Panasonic Corporation, Japan; hereafter "PC").

The J-RSR is a task in which the participant chooses a road sign appropriate for the road situation. In the photographs presenting the road situations, the road signs are obscured via photo editing. The participant is asked to evaluate the road situation and choose the most appropriate road sign (Fig. 1). Each question is worth one point and there are ten questions in total. The PC records the number of correct answers, the road signs chosen, whether these signs are correct or not, and the total time taken to answer the questions.

As for the TMT, a new version was developed wherein the arranged stimulus from the paper version is placed onto the PC screen at the same ratio. The major differences between the paper and PC versions of the TMT are a) when the correct target is touched, the PC produces a target sound indicating a correct answer, and when an incorrect target is touched, it produces a sound indicating an incorrect answer, and b) all targets remain on the screen even after the correct target is touched. Preceding studies have found that part B of the TMT (TMT-B) requires more time to complete and produces more incorrect answers than does part A (TMT-A) [26]. The PC records the time taken to complete the task and the number of correct and incorrect answers. When the time taken to complete the task exceeded five minutes, it was treated as a missing value.

The program for the tasks was constructed by Nishizawa Electric Meters Manufacturing Co., Ltd.

Fig. 1. An example of the Road sign recognition test. The participant chooses a road sign appropriate for the road situation. For this question, Option 1 is the correct road sign.

Analysis

The result of each task was compared between the older and younger groups. In the case of the J-RSR, the comparisons were made between the number of correct answers, the time taken to complete the task, and the correct answer rate for each question. In the case of the TMT, comparisons were carried out in terms of the time taken to complete the task and the number of incorrect answers. Unpaired t-tests were used for all statistical analyses, and the significance level was set at 5% for all analyses.

Results

There were no statistically significant differences between the two groups in the number of correct answers on the J-RSR (t (85) = −0.80, p = 0.43; older group: 8.2 ± 1.7 [range: 4−10]; younger group: 8.5 ± 1.2 [range: 5−10]; Fig. 2-a). On the other hand, the older group took significantly longer to answer the questions (t (85) = 7.20, $p < 0.000001$; older group: 246.0 ± 113.8 seconds; younger group: 114.7 ± 40.8 seconds; Fig. 2-b). As for the correct answer rate for each question, in the case of Question 1, 46.5% of the older group answered correctly, while 68.2% of the younger group answered correctly; this difference in favor of the younger group was significant (Z = −2.05, $p < 0.05$). There were no significant differences between the two groups for any of the other questions (Table 1). There was an interesting finding for Question 1: while the correct answer is option 1, many of those from the older group who answered incorrectly chose option 3, whereas those who answered incorrectly among the younger group had evenly distributed answers among options 2−4 (Fig. 3).

In the case of the TMT-B, one participant from the older group took more than five minutes to complete the task; this participant's answer was thus treated as a missing value. The older group took significantly longer to complete the tasks for both the TMT-A and the TMT-B (TMT-A: t (85) = 7.96, $p < 0.000001$; older group: 73.8 ± 19.5 seconds; younger group: 48.0 ± 9.0 seconds; TMT-B: t (84) = 9.70, $p < 0.000001$; older group: 133.3 ± 45.6 seconds; younger group: 62.2 ± 16.4 seconds; Fig. 4-a). There was no significant difference between the two groups in terms of the number of incorrect answers on the TMT-A (t (85) = 1.33, $p = 0.19$; older group: 0.6 ± 2.6 times; younger group: 0.0 ± 0.3 times). However, on the TMT-B, the number of incorrect answers was significantly higher for the older group (t (84) = 4.53, $p < 0.00001$; older group: 2.6 ± 3.4 times; younger group: 0.3 ± 0.5 times; Fig. 4-b).

Table 1. Percentages (%) of correct answer between the two groups. No statistically differences were found between the two groups other than Question 1.

	Older (N = 43)	Younger (N = 44)	Statistical value (p value)
Q.1	46.5	68.2	Z = −2.05 ($p < 0.05$)
Q.2	90.7	97.7	n.s.
Q.3	69.8	61.4	n.s.
Q.4	90.7	81.8	n.s.
Q.5	95.3	97.7	n.s.
Q.6	74.4	77.3	n.s.
Q.7	90.7	81.8	n.s.
Q.8	93.0	97.7	n.s.
Q.9	83.7	93.2	n.s.
Q.1O	86.0	88.6	n.s.

n.s.; not significance

Discussion

As far as we know, there have been reports on four kinds of tests using road signs. Carr et al. [27] developed the traffic sign naming test and reported that the test can differentiate between patients with dementia of

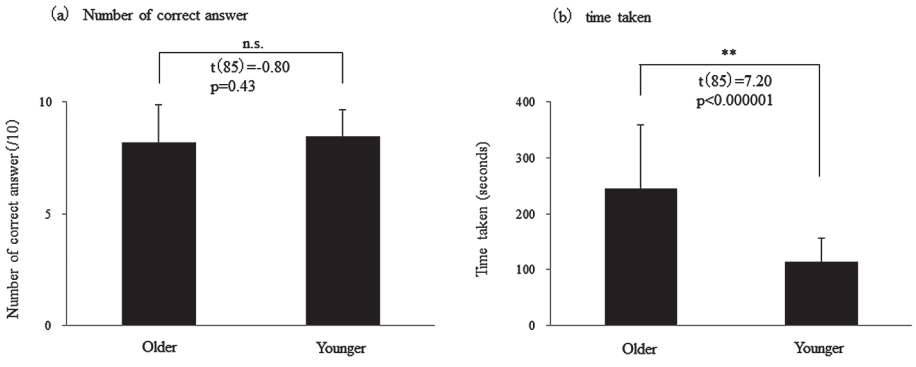

Fig. 2. Results of the road sign recognition test.
For the number of correct answer, no statistically significant differences were found (a), while the older group took significantly longer to answer the questions (b). n.s.; not significance, **; $p < 0.000001$

	1	2	3	4
Older (N=43)	20	5	15	3
Younger (N=44)	30	4	4	6

Fig. 3. Distribution of participants' response in the Question 1 (The correct answer is option 1). Many of those from the older group who answered incorrectly chose option 3, whereas those who answered incorrectly among the younger group had evenly distributed answers among options 2−4.

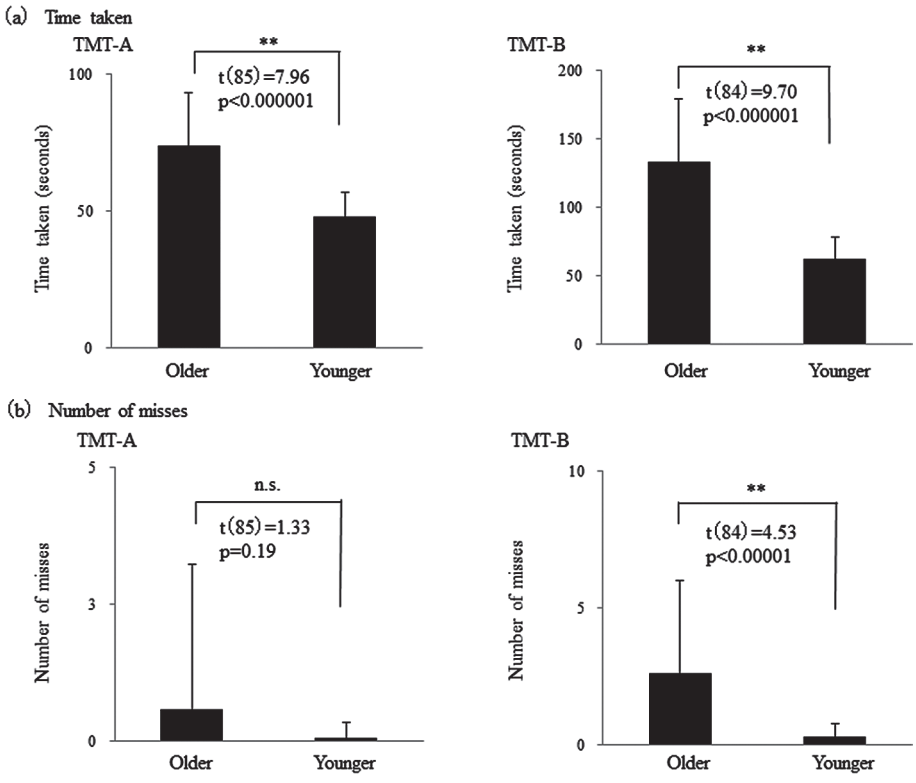

Fig. 4. Results of the TMT-A and the TMT-B.
The older group took significantly longer to complete the tasks for both the TMT-A and the TMT-B (a). While there was no differences between the groups for the number of misses on the TMT-A, older group showed significantly higher number fo incorrect answeres on the TMT-B. n.s.; not significance, **; $p < 0.000001$

the Alzheimer's type (AD) and neurologically healthy elderly people (healthy). This task uses photographs of actual road signs and requires participants to identify their meaning. Since this test only addresses knowledge of road signs, it is very different from the J-RSR, which requires the subject to comprehend the road situation from a photograph and to choose a road sign appropriate for that situation. Uc et al. [28] examined the Landmark and Traffic Sign Identification Task and reported that it can differentiate AD from healthy subjects. The test measures how many landmarks and signs that appear in a driving video can be identified. While it does require visual searching ability, it does not require knowledge of road signs, which makes it different from the J-RSR. Brown et al. [29] examined the driving scenes test, wherein the subject is consecutively shown two color drawings of a road situation, separated by a brief interval, and is then required to point out the differences between the two drawings. This test requires visual memory capacity, not knowledge of road signs, which means that completing it requires different abilities than those required for completing the J-RSR. While the RSR in the SDSA [18, 21, 30, 31] is very similar to the J-RSR, as pointed out in the introduction, it differs from the J-RSR in that it uses drawings, not photographs; furthermore, it does not present Japanese road situations. These findings suggest the novelty of the J-RSR.

It has been reported that the RSR is predictive of the results of on-road evaluations (Lincoln et al., 1992, [5, 20, 21, 31−33]. The RSR is a complex task that requires good visual cognition, mental speed, working memory, executive function, and non-verbal reasoning simultaneously [21, 23−25, 34]. Each cognitive faculty is necessary to drive a car. Since the major difference between the J-RSR and RSR is the fact that the former uses photographs of road situations in Japan while the latter does not, they can be considered to assess the same cognitive faculties. Our analysis of the results showed that while there is no difference between older and younger driver's license holders in the number of correct answers, the younger group was faster at answering the questions. This suggests that while there is no difference between the two groups in terms of the ability to evaluate a driving situation or choose an appropriate road sign, there is a difference in mental speed to reach the conclusion. In other words, the result highlights that, among all cognitive faculties necessary to complete the task, the primary difference between the groups was in mental speed. This assumption is supported by the fact that the younger group was significantly faster in the TMT. However, analysis of the correct answer rate for each question indicates that the results cannot be explained by mental speed alone (Fig. 3). In Question 1, the subject is required to comprehend a situation in which "one cannot go straight ahead" and to choose the road sign that reflects that situation. Option 1 (the correct answer) is a "no vehicle entry" sign, option 2 is a "maximum speed 50km/h" sign, option 3 is a "stop" sign, and option 4 is a "no vehicle entry except bicycles and motorcycles" sign. Many of the older participants who chose the incorrect option chose option 3, while younger participants' incorrect answers were evenly distributed over options 2−4. The fact that the answers were not distributed evenly suggests that there are trends present in comprehending the situation. It has been inferred that the difference in the distribution of answers is related not to mental speed but to differences in the ability to comprehend situations based on driving experience [35, 36]. Preceding studies on the RSR including older people have reported that in a 12-point test, the older drivers' median score was 7 (interquartile range 6−10; [20]) and the mean was 8.2 ± 2.4 (range: 2−12; [30]). In comparison to these reports, the results of the present study suggest a higher correct answer rate. In order to examine the effectiveness of the J-RSR as an evaluation of driving ability, future investigations among stroke and dementia patients must be performed. In relation to the errors that we identified that are caused by cognitive factors other than mental speed, tests should be carried out among patients with brain damage who show symptoms of reduced cognitive function.

Acknowledgments: This study was performed with the support of a Grant-in-Aid for Young Scientists (B) (Grant number 26750182). We are grateful to Mr. Hideya Momose of Nishizawa Electric Meters Manufacturing Co., Ltd., for his exceptionally valuable program development advice.

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■CASE REPORT

Therapeutic Value of Using Two-step Splinting for Mallet Finger

Kazuo Saito[1], Hitoshi Kihara, MD[2]

[1] Department of Rehabilitation, Fuchinobe General Hospital
[2] Kihara Orthopaedic Clinic

Abstract: In the present study, we report two cases of splinting therapy where favorable results were obtained using splinting of two types, consisting of a first step of fixation at PIP joint extension position and DIP joint extension position, followed by a second step of further fixation at DIP joint extension position, followed thereafter by hand therapy on mallet finger. As the first splint flexes the PIP joint, and, further, as the DIP joint is taken as the hyperextension position, it is thought that the ruptured tendon ends sufficiently entwined more than with the conventional splint at the DIP joint extension position. The splinting therapy we used, with its two-type splinting, is thought to have enabled fixation and ROM acquisition that were in tandem with the tendon healing process. This treatment hints at the effectiveness of conservative therapy in the treatment of swan neck deformities and bony mallet finger.

Keywords: tendinous mallet finger, bony mallet finger, two-step splinting, hand therapy

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Introduction

Generally, conservative therapy is used to treat mallet finger. For simple closed mallet finger, surgery is controversial because results of studies indicate that splinting is effective. Nevertheless, surgery is indicated under certain conditions [1, 2]. However, difficulties often arise in such cases because of extension lag. Thus, fixing a splint with slight extension at the distal interphalangeal (DIP) joint is often used in conservative treatment [2−6]. The standard recommendation is splinting for ≥ 6 weeks, followed by active movement [2, 4]. The splinting method has not been standardized, and various techniques have been reported. Research on specific fixing methods used in conservative treatment of mallet finger includes studies on the effectiveness of fixing the proximal interphalangeal (PIP) and DIP joints by Wehbé and Schneider [7], Evans [8], and O'Conner [9], but their studies did not include comparisons of the immobilization duration or types of splints. Pike et al. [10] and O'Brien and Bailey [11] compared three types of splints, and both studies concluded that custom thermoplastic splints, which are custom-made for each patient, were most effective.

Considering that sufficient improvement of extension lag has not been obtained through splinting of the DIP joint alone, we believe that improved results could be observed by studying splinting of the PIP joint [7−9] and splinting duration. We believe so because we thought that while splinting the PIP and DIP joints does sufficiently draw together the ruptured tendon portions and that this would be a favorable position for repair of the terminal tendon, long-term immobilization would result in PIP joint contracture. Thus, to minimize PIP joint contracture, we thought that if we removed only the PIP joint splint at 2 to 3 weeks and then retained only the DIP splint, we could then correct the DIP joint extension lag.

We also believe that the key to the success of this approach would be having a hand therapist create a custom-made thermoplastic splint for each patient.

The present study aimed to determine the therapeutic values of two methods of splinting that involved initial fixation at the PIP and DIP joint extension positions, followed by further fixation at the DIP joint extension position, and then by hand therapy. Herein, we report splint therapy cases in which favorable results were

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Corresponding to: Kazuo Saito, Department of Rehabilitation, Fuchinobe General Hospital, 3-2-8 Fuchinobe, Chuouku, Sagamihara-City, Kanagawa, 252-0206, Japan
e-mail: kasuo_saitoh@yahoo.co.jp
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obtained by using the two methods of splinting. This study was conducted after providing sufficient explanations to the subjects and obtaining their consent.

Methods

In this paper, we describe the splint therapy that we designed and the follow-up hand therapy, and report 2 cases, 1 each of tendinous and bony mallet fingers.

The protocols for the two-step splinting and hand therapy were as follows (Fig. 1):

1) Two-step splinting (Table 1)

Step 1 was performed up to 2 or 3 weeks after injury; it involved creating the splint for DIP joint hyperextension and 45°-flexion position of the PIP joint. The splint material used was a 1.6-mm Orfit soft-type material (Orfit Industries n.v. Belgium) and the splint was created with a full-circumference mold. Then, 2- or 3-week fixation was performed (initial splinting).

Step 2 was performed from 2 or 3 weeks to 6 weeks; after 3 weeks' fixation with the first splint, we created a splint for the DIP joint slight extension position. By using a 1.6-mm Orfit soft-type material, a figure-8 splint was created. Here, 3-week fixation (second splint) was performed (total splint-fixation duration: 6 weeks). Subsequently, a DIP joint (night splint) was used for 12 weeks, with constant monitoring of the subject's condition. During this period, active range of motion (ROM) was initiated, but because the extension lag of the DIP joint became aggravated, splint use was increased from nighttime only to 24 hours [2, 4] (Fig. 1).

2) Hand therapy

Six weeks from the initiation of therapy, active exercise was initiated at the rehabilitation clinic. In cases

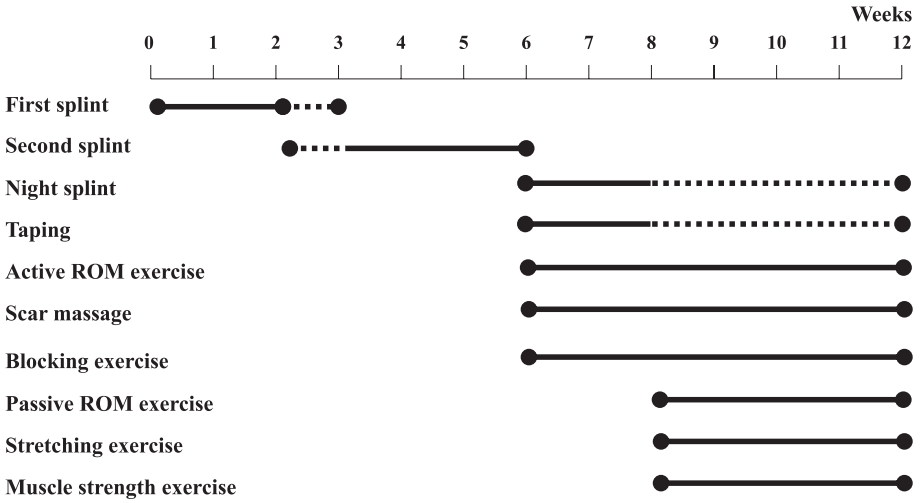
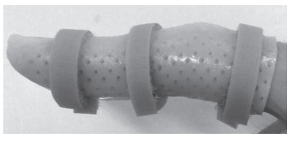
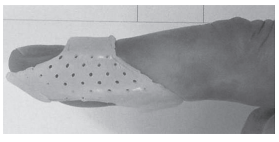


Fig. 1. Two-step splinting protocol and hand therapy.

Table 1. Two-step Splinting.

	First step	Second step
Appearance		
Position	DIP joint mild extended position PIP joint flexion 30−45°	DIP joint mild extended position
Splint type	Circumference type	Eight figure type
Material thickness	1.6 mm	1.6 mm
Term	2 or 3 weeks from initial visit	3 or 4 weeks after the first step splint Total 6 weeks
Mounting time	Throughout the day	Throughout the day

where swelling remained on the dorsal side of the DIP joint, scar massage was performed from the proximal to the distal area, after the swelling was reduced. DIP joint blocking training was performed. The patient wore the splint in the time when there was no training (Table 2). Eight weeks from the initiation of therapy, other movement exercises and stretching were added. Muscular strengthening exercises of the extensor tendon were performed, with gradual increase of exercises. Muscular strength training of the extensor tendon consisted of gradually increasing the time and weight of pinch exercises, and extension resistance exercises, along with the use of Ceraplast. At first, the resistance time was short and the load was light, and the subject was monitored for pain and fatigue when the soft-type Ceraplast was used. Harder materials were gradually introduced (Table 2). Taping was performed mainly on the dorsal side of the DIP joint in a figure-8 configuration to offer support to prevent hyperflexion of the joint (Table 2). Taping was also instructed if the patient intended to the finger ends during the daytime. The areas indicated by the dotted line are sites subject to consultation with the physician during monitoring of the improvement of the extension lag (Fig. 1).

Case Report

Case 1 was a severe DIP joint flexion deformity due to tendinous mallet finger and a swan-neck deformity. Case 2 was a bony mallet finger that was treated with conservative therapy.

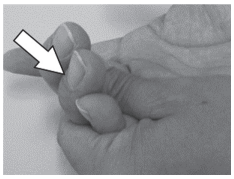
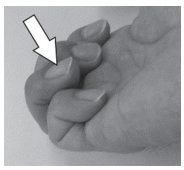
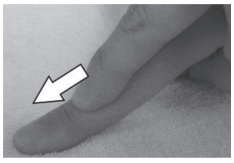
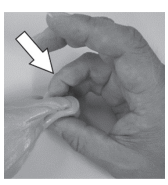
Case 1 was observed in a woman aged 27 years. Her left little finger was injured by a tape cutter that had fallen from a high place. Two days thereafter, she was examined at our hospital and diagnosed with a tendinous mallet finger on radiography. She had no notable medical history. She presented a swan-neck deformity at the initial examination (Fig. 2).

On day 2 after the injury, the first splint was created and was affixed for 3 weeks. Thereafter, the second splint was created and was affixed for 3 weeks (total splint-setting period: 6 weeks), and ROM training consisting of DIP joint active movement was initiated. Scar massage was performed, and at 8 weeks after injury, other movement exercises, stretching, and muscular strength training were initiated. The DIP joint ROM over time in terms of extension/flexion was as follows: at the time of injury, −60°/60°; 6 weeks after injury, 10°/30°; and 12 weeks after injury, −5°/60° with pain within manageable bounds. The patient was able to return to her part-time job at a convenience store. Her condition was classified as good according to the Crawford evaluation criteria [11]; the results are shown in Table 3 and Fig. 2.

Case 2 was observed in a man aged 28 years. His right ring finger was injured when it became stuck in a refrigerator while working. Three days thereafter, he was examined at our hospital and diagnosed with a mallet fracture on radiography. According to the Wehbé and Schneider classification system [7], the injury was classified as a type IIB injury. The patient had no notable medical history (Fig. 3).

On day 6 after injury, the first splint was created and worn for 2 weeks. Thereafter, the second splint was

Table 2. Hand therapy for 6 weeks and 8 weeks (ring finger).

6 weeks	8 weeks
1. Active ROM exercise	1. Passive ROM exercise
2. Blocking exercise 	2. Stretching Hook fist  Full fist 
2. Scar massage Proximal → distal 	3. Muscle strength exercise Pinch exercise  Extensor exercise 
3. Taping During the daytime at work 	

Direction of the arrow indicates the movement of the injured finger

Table 3. Case 1: Course of treatment (left little finger).

	1 week	2 weeks	6 weeks	12 weeks	Outcome
DIP Ex/Flex	−50/60	20/−20	10/30	−5/60	Crawford
Pain VAS	7/10	3/10	1/10	0/10	evaluation criteria
Work	Leave of absence	Some return	Some return	Full return	**Good**

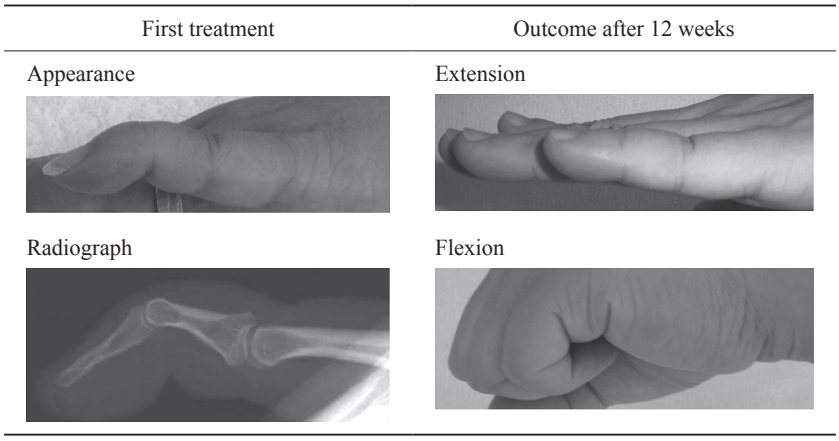


Fig. 2. Case 1: First treatment and outcome after 12 weeks (Left little finger with tendinous mallet finger).

created and worn for 4 weeks (total splint-setting period: 6 weeks), and ROM training via DIP joint autonomous movement was initiated. Scar massage was performed, and at 8 weeks after injury, other movement exercises, stretching, and muscular strength training were initiated. The DIP joint ROM over time in terms of extension/flexion was as follows: at the time of injury, −40°/50°; 6 weeks after injury, 20°/30°; and 12 weeks after injury, 5°/50°, with pain within manageable bounds and no pain during carrying tasks. This injury was classified as perfect according to the Crawford evaluation criteria [12]; the results are shown in Table 4 and Fig. 3.

Discussion

Anatomically, the balance between the central slip of the extensor hood at the PIP joint and the terminal extensor tendon at the DIP joint is important for finger function and appearance. Loss of the terminal extensor tendon attachment leads to the central slip receiving all tension. The PIP joint will thus have a resting tone in extension or even in hyperextension. With the flexed posture of the DIP joint, this would present as a swan-neck deformity [4, 12, 13]. In mallet finger, the extent of the DIP joint flexion deformity is thought to be proportional to the extent of the separation of the ruptured tendon ends in the ruptured tendon portion within the DIP joint extension position [13].

As the first splint flexes the PIP joint and as the DIP joint is considered the hyperextension position, the ruptured tendon is thought to be sufficiently entwined, more than with the conventional splint at the DIP joint extension position. Considering the tendon repair process, a remarkable proliferation of fiber cells and fibroblasts could be observed at the tendon cross-sectional area at approximately 3 weeks, and tendon tensile strength increased [14]. At this time, the splint was changed to a conventional splint at the DIP joint extension position. This change allowed exercise of the PIP joint, and thereby, is thought to have minimized the PIP joint contracture.

Because case 1 had a severe terminal tendon injury, the lateral band and oblique retinacular ligaments were translocated to the dorsal side, presenting a swan-neck deformity [12]. Therefore, in order to sufficiently reposition the terminal tendon, we planned to fix the finger in the DIP joint hyperextended position for 3 weeks to flex the PIP joint and transpose the lateral band and oblique retinacular ligaments to the volar side.

This suggests that in a case such as case 2, where a bony mallet finger is classified as type IIA or lower according to the Wehbé and Schneider classification system [7], even if this is an obsolete case, good fixation positions can be preserved and synostosis is possible.

In case 2, radiography showed DIP joint extension only, indicating that repositioning of the bone fragment could be achieved through PIP joint flexion and DIP joint extension. The splint was fixed at that position,

Table 4. Case 2: Course of treatment (right ring finger).

	1 week	2 weeks	6 weeks	12 weeks	Outcome
DIP Ex/Flex	−30/30	20/−20	20/30	5/50	Crawford
Pain VAS	8/10	5/10	0/10	0/10	evaluation criteria
Work	Some return	Full return	Full return	Full return	**Perfect**

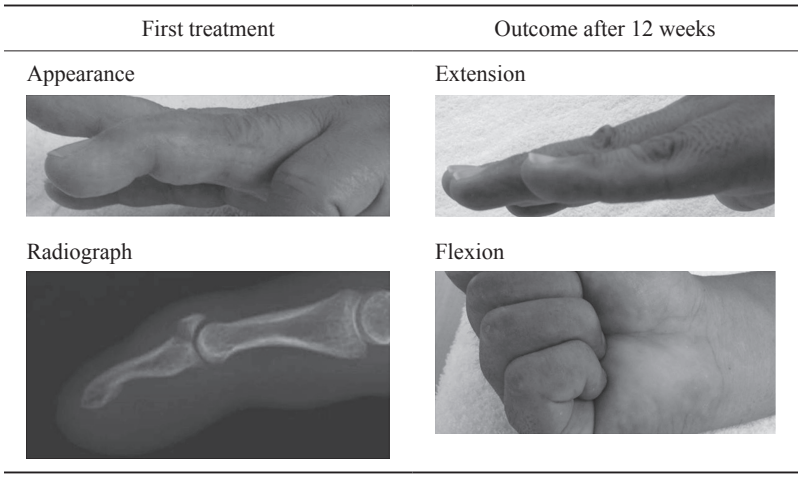


Fig. 3. Case 2: First treatment and outcome after 12 weeks (Right ring finger with bony mallet finger).

which allowed fixation at a position where the terminal tendon was sufficiently loose [2, 4, 12].

The success of the two-step splinting used in this study was owing to the fact that anatomically, the tension on and looseness of the extensor tendon was maintained in the early stages. Thereafter, switching to a splint that fixed the minimum amount of the digit prevented excess contraction and led to improvement of ROM. For the creation of the first splint, it is important to correctly understand the characteristics of thermoplastics and be familiar with the materials. Moreover, care in the casting is important to ensure that no pressure is applied at the sides of the finger or at the dorsal side of the DIP joint. To increase the possibility of successful fixation of the splint for a continuous period of ≥ 6 weeks, the splint should be custom-fit for each patient. Custom-made, two-step splinting is thus thought to be effective. The splinting therapy that we used, with its two splinting methods, is thought to have enabled fixation and ROM acquisition that were in tandem with the tendon healing process. In the future, we will accumulate more cases of using this fixation method and investigate, for example, the differences between the two splinting methods and fixation of the DIP joint only, as well as the application of our splinting method to residual mallet finger. This treatment hints at the effectiveness of conservative therapy in the treatment of swan neck deformities and bony mallet finger.

In the future, we would like to continue our study of this treatment but with larger numbers of subjects and with attention paid to splint-related complications such as dorsal skin maceration and necrosis [15]. We would also like to compare conventional treatments with the two-step splint method. Finally, we would like to investigate the applicability of our treatment method to obsolete cases of tendinous and bony mallet fingers.

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■ORIGINAL ARTICLE

An Occupational Performance Patterns of Family Members of Terminal Cancer Patients: Typology of family palliative caregivers and occupation performance patterns

Seigo Minami[1], Ryuji Kobayashi[2]

[1] Faculty of Allied Health Sciences, Yamato University, Japan
[2] Department of Occupational Therapy, Tokyo Metropolitan University, Japan

Abstract:
Objective/Background: In this study, we classified the psychological adjustments of family members of terminal cancer patients using a conceptual structure based on recurring cases. We hypothesised that it is possible to determine the need for intervention on the basis of the occupational performance patterns of the family members.
Methods: The subjects were bereaved family members of cancer patients who died more than a year ago. For our classification system, we adopted code matrix analysis using MAXQDA10 analysis software.
Results: We categorised the 9 cases into 3 types on the basis of functionality with regard to occupation: i) type of continued occupation; ii) type of resumed occupation; iii) type of interrupted occupation.
Conclusions: The categorisation of occupational types assumes that occupation has an effect on the family members' ability to progress through or alter mental states according to occupational performance patterns.

Keywords: occupational therapy, family caregivers, occupational performance

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Introduction

Caretakers of family members with terminal cancer often experience both sorrow and grief following the loss of the patient. Lindemann [1] noted that grief does not only occur only after bereavement; instead, it begins upon the anticipation of death. He called this phenomenon 'anticipatory grief'.

It is normal to experience grief after the loss of a loved one. However, if this grief continues for an excessive period or disrupts daily life, it is conceivable that the grieving person has fallen into a state of psychological crisis due to pathological grief. Caplan [2] defined such a psychological crisis caused by pathological grief as a situation in which a person faces obstacles against an important goal in life. In other words, the person is in a situation where he tries to solve the problem in the way that he has done habitually, but he cannot overcome the problem.

Occupational therapy is a method to encourage the grieving person to avoid a state of psychological crisis through occupation [3]. To the best of our knowledge, no previous report, other than ours [4], has shown the efficacy of occupational therapy as support for families experiencing pathological grief. In the present study, we studied families who took care of patients with terminal cancer at home and clarified a conceptual structure categorizing the effects of occupation on psychological adjustments of the families using a grounded theory approach [5]. However, our findings were comprehensive and did not reflect the characteristics of individual cases or support specific interventions. Accordingly, we decided to pursue additional data analysis on a case-by-case basis because it is important to clarify relationships between occupational performance patterns and alterations in the mental state. Thus, we supposed that it would be possible to determine the need for intervention on the

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Corresponding to: Seigo Minami, Faculty of Allied Health Sciences, Yamato University, Japan, 2-5-1 Katayamachou Suita-shi, Osaka, 564-0082, Japan
e-mail: minami.seigo@yamato-u.ac.jp
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basis of occupational performance patterns observed in each case.

This study coordinated the talk of subjects along six categories obtained in the preliminary research that Minami et al. [4] was contributed to Hong Kong Journal of Occupational Therapy. The purpose of the present study was to clarify the occupational performance patterns and types of occupation of family members of cancer patients using the 'case-category matrix method' in order to identify factors that contribute to alterations in the mental state due to pathological grief.

Methods

Survey period

The survey period was 5 months, from February 2011 to June 2011.

Subjects

The study subjects were family members who provided in-home palliative care for patients with terminal cancer and were selected using convenience sampling methods. The subjects were spouses, children or grandchildren of the patients. They individually interviewed by 4 medical staff members in order. . Each patient received palliative care during the final stages of illness. Palliative care focuses on pain management without the use of anti-cancer agents, which are generally administered during intensive care. Moreover, we chose subjects whose family members had died more than a year before participation in this study because we considered a period within 6 months after death to be a 'grief work' period, although the duration of this period is reportedly dependent on the age of the caregiver [6, 7]. The Schnabel method was used to qualitatively measure theoretical saturation conditions [8]. The Schnabel method can express a trapping rate in a reasonable viewpoint. To determine whether the theoretical sampling was successful, we calculated and evaluated the trapping rate when new findings began to gradually cease. At this time, if the label had an overall trapping rate of ≥ 90%, we considered it to indicate theoretical saturation. The study protocol was approved by the Ethical Review Board of Kibi International University (approval number: 10−17).

Creation of a case–category matrix

To create a case–category matrix, we placed core categories that were identified in our previous study on the horizontal axis and the cases recruited in this study on the vertical axis. In each of the cells, we provided a paraphrased version of comments from the family member who provided care; these comments were obtained during case interviews regarding the corresponding core categories [9]. In addition to studying the case–category matrix as a whole, we arranged the details of each case into a story centred on the core categories and classified each case on the basis of similarities between these stories. The core categories were 'being overwhelmed by pressure', 'occupation while living with the illness', 'living without being overwhelmed by anxiety', 'having difficulties in regulating emotions', 'comforting memories of the occupational experiences' and 'leading to a change in emotions' [4].

Summary of subjects

In total, 9 cases were included in this study. The Schnabel method yielded a result of 94.8%, indicating that these 9 cases provided theoretical saturation. The attributes of the included cases were as follows: (i) the average [± standard deviation (SD)] period of home palliative care was 7.2 ± 6.9 months; (ii) the average length of time since the patient's death was 44.8 ± 28.2 months; (iii) the average age of the caregiver was 50 ± 19.9 years and (iv) the average age of the deceased cancer patient was 60 ± 10.8 years (Table 1).

Results

We obtained occupational performance patterns from the 'case–category matrix' (abridged edition) on a case-by-case basis. As shown in Table 2, case no. 1 fell into the category labelled 'thoughts are continued', no. 2 fell into 'thoughts are continued', no. 3 fell into 'work is insufficient'. no. 4 fell into 'work is insufficient', no. 5 fell into 'thoughts are continued,' no. 6 fell into 'thoughts are continued,' no. 7 fell into 'resumed former hobbies', no. 8 fell into 'resumed former hobbies' and no. 9 fell into 'work is insufficient'.

In addition, occupational performance patterns were categorised into 3 occupational types: (i) 'occupation continued', (ii) 'occupation resumed' and (iii) 'occupation interrupted'. The distribution of occupational patterns was as follows: (i) 'occupation continued': case nos. 1, 2, 5 and 6; (ii) 'occupation resumed': case nos. 7 and 8 and (iii) 'occupation interrupted': case nos. 3, 4 and 9 (Table 2). Moreover, we found that after the death of the patient, alterations in the mental state were associated with occupation types as follows: in both the 'occupation continued' and 'occupation resumed' types, alterations in the mental state were promoted, and in the 'occupation interrupted' type, alterations in the mental state were incomplete (Table 2).

Here, we specifically describe the occupational performance patterns along with the story of each case, beginning before the cancer patients died.

Table1. Characteristics of family members and patients.

Subject	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9
Gender	W	M	W	W	M	W	W	M	W
Age	60s	30s	50s	50s	50s	60s	50s	90s	20s
Attribute participant	wife	son	wife	wife	son	daughter	wife	husband	GC
Attribute patient	husband	father	husband	husband	mother	mother	ML	wife	GF
Palliative care period at home	9 months	1 year	14 days	1 month	6 months	2 months	6 months	5 months	2 years
After the death	1 years 10 months	2 years 6 months	1 year 5 months	2 years 6 months	7 years	1 year 6 months	7 years	7 years	3 years
Diagnosis of cancer	Informed to the patients	Informed to the patients	Informed to the patients	Informed to the patients	Not informed to the patients	Not informed to the patients	Not informed to the patients	Not informed to the patients	Not informed to the patients
Interview time	97 minutes	41 minutes	59 minutes	91 minutes	38 minutes	44 minutes	47 minutes	88 minutes	114 minutes

GC: grandchild; GF: grandfather; M: man; ML: mother-in-law; W: woman

1) 'Thoughts are continued': case nos. 1, 2, 5 and 6

Case no. 1 was a woman who cared for her sick husband. During his illness, the couple spent time gardening, walking, enjoying *tanka* (a 5-line, 31-syllable Japanese poem) and reciting Chinese poems. 'One day', the wife recalled, 'the doctor told us, "Even if your husband has surgery, I don't expect that he can survive." Therefore, my husband told the doctor that he didn't want to be hospitalised or have surgery. Instead, he wanted to receive home palliative care'. One of the reasons why this patient wanted to receive palliative care at home was that he wanted to help care for his sick mother. His wife, who respected her husband's decision, devoted her time to care for her husband and his sick mother. After her mother-in-law died, she accompanied her husband to the funeral.

At the funeral, however, her husband's condition was critical: his lips were blue and he was barely able to stand. His wife supported him and monitored his condition. In addition, she kept a notebook in which she described his fight against his illness. After he died, she re-read her notebook and composed it in *tanka* form, which was her hobby, and turned this narrative into an anthology for her children. She also worked in the garden, which became her sole responsibility after her husband became ill. She continues to take early morning walks and compose *tanka*.

Case no. 2 was a man who cared for his sick father. While his father was fighting his illness, he enjoyed gathering his family members around the dining table for casual conversations. The father reminisced about his life and upbringing, requested that his son look after particular matters after his death, spoke to his relatives about being good members of the society and maintaining a strong family unit and so on. During these heartfelt conversations, the son was able to embrace his feelings towards his father, and this time offered them a chance to become closer than they ever had been. The father also shared his passion for photography with his son, which had been one of his favourite activities. The father told his son that he could not take pictures any longer because his condition was becoming prohibitively worse. Thus, the son took his father's camera, photographed scenes of a mountain they had once visited together and shared them with his father. When the father saw the pictures, he happily said, 'My son continues to pursue my hobby'. The son values the camera till date.

Case no. 5 was a son who cared for his sick mother. Before his mother died, the son continued to live his life normally, while also discussing his work and his children's education with his mother. While the mother was fighting her illness, the son was unable to visit her during the final stage of her life because he was working out of town. Therefore, when he returned, he supported his children, wife and father who had been taking care of his mother. He appreciated the support of his immediate family, who served as primary caregivers, and acknowledged their tireless efforts and valued his relationships with them as it reflected in his mother's care. After his mother died, he realised the importance of the support of his family members during times of illness. He now feels that his family ties have deepened because of sharing the common experience of fighting against an illness.

Case no. 6 was a daughter who cared for her sick

Table 2. Abridged edition/case-category matrix.

Switching of mental state	type of occupation	Occupational-performance pattern	No.	categories (examples)	
				being overwhelmed by pressure	occupation while living with the illness
Promotion	type of continued occpation	Thoughts are continued	Nos. 1, 2, 5, 6	My husband often woke me up in the middle of the night because of which I couldn't get sufficient sleep. I suffered from dizziness. I was so tired that I went to the hospital without letting my husband know. After my doctor told me about his cancer, it was difficult for me to accept the reality of the situation. (No. 1)	My husband and I ate, went for walks, took care of the garden, sang "kouta" (a ballad sung to shamisen accompaniment) and together cared for my mother-in-law at home. My husband taught me about gardening and bonsai. Other family members continued singing tanka, which is our hobby, and they accompanied us for walks in the mornings. I wrote about my husband's condition and the events of each day in detail in my notebook. (No. 1)
	type of resumed occupation	Resumed former hobbies	Nos. 7, 8	My mother-in-law was often scared at night, so she had someone to stay with her and hold her hand. It was painful for me to see my mother-in-law becoming weaker every day. Although care was needed at all times, my mother-in-law did not like the fact that she needed such care. I did not know what to do. (No. 7)	I harvested in our field and cooked with my mother-in-law. It was refreshing to continue working. (No. 7)
Incomplete	type of interrupeted occupation	Work is insufficient	Nos. 3, 4, 9	My husband lost weight during the week after his doctor told him about his terminal cancer. I was more scared than worried. My husband could not get up on his own at all. I had to pull him up and help him go to the washroom. Our family members were exhausted from taking care of him. (No. 3)	Because my husband was self-employed, I helped him with his work. When my husband was hospitalized, he wanted to smoke. I would take cigarettes for him at the hospital. I also helped him move about when he was bedridden. (No. 3)

mother. While her mother was fighting her illness, the daughter provided in-home palliative care without informing her mother of her cancer. Other family members worked hard to maintain her everyday life without letting her realise that she had cancer, while providing the most devoted care possible all the time. One day on *Tanabata* (the Star Festival), the mother wrote a *tanzaku* (a strip of fancy paper to write wishes on) with her family, including her grandchildren. The mother wrote on the *tanzaku*, 'Everyone is very devoted to me this year. Thank you. Thank you. Thank you'. The family members who saw that *tanzaku* were heartbroken. After her mother's death, the daughter still treasures that *tanzaku* as it portrays her mother's feelings of gratitude. Even now, she continues to embrace the feelings of emotional support from the note.

2) 'Resumed former hobbies': case nos.7 and 8

Case no. 7 was a woman who cared for her sick mother-in-law, who had no knowledge of her cancer. Therefore, the woman continued to avoid letting her mother-in-law realise that she had cancer. In spare moments during her illness, the mother-in-law often invited her daughter-in-law to her room and expressed her feelings of gratitude. On the day when the mother-in-law died, the woman was at work and was therefore unable to see her during the final moments of life. She experienced bitterness about this; however, the fact that she was able to offer her mother-in-law a sense of family unity and the memories of her mother-in-law's expression of gratitude provided her emotional support. The most cherished memory of the woman was that she was able to spend time with her mother-in-law at home until the end, while they mutually supported each other

living without being overwhelmed by anxiety	having difficulties in regulating emotions	comforting memories of the occupational experiences	leading to a change in emotions
Our family members could talk with my husband about events when we went for a walk in the morning. My husband encouraged me to take walks on my own as well, as they helped me feel calm. Our family members also helped each other. I supported my husband in what he wanted to do. Even when my husband couldn't walk anymore, we went to buy a new potted plant and had a suit made together. (No. 1)	Once or twice a month, I experienced sudden shortness of breath and lack of motivation, and I am being treated for this at the hospital now. When I stayed home too much, I would feel suffocated. Going out rather than staying home all the time is therapeutic for me, so I try to go out. (No. 1)	I was able to care for both my husband and my mother-in-law at home. I was also able to make a songbook that I had promised my husband I would make. This songbook also documented the events that were recorded in my notebook. Even now, I still take good care of the garden that my husband and I planted together. Without these things, I would have been overwhelmed. Taking over my husband's hobbies helped me feel connected to him because I started thinking like him and following his lifestyle. (No. 1)	Some of my friends invited me to go on a trip together. My family members have stayed with me. Some of my husband's belongings are still here. I still take good care of the potted plant that my husband bought during his final stage. I still feel that my husband is somewhere close to me. (No. 1)
Our family ensured that my mother-in-law could do what she wanted. My work improved my mood, and I eventually decided to ask caregivers to take care of my mother-in-law. (No. 7)	My only regret is that I could not be with my mother-in-law during her final stage. (No. 7)	I was relieved because my mother-in-law wrote to me about her feeling of gratitude while she was fighting against the disease. Also, after my mother-in-law's death, I was encouraged by my family members who gathered around me. (No. 7)	I have starting reading the picture books that I collected as a hobby and other picture books that were given to me by my friends. (No. 7)
I always hoped that I would be able to work with my husband if he were to recover completely. On the day before my husband died, he said, "I want to eat anpan (a round soft bread with azuki bean jam in its center)." He ate all the anpan, even though he later vomited it all. He told us that he wanted to live. His doctor and nurses offered him a lot of support. (No. 3)	It is painful to see pictures of my husband around the house. Even now, I sometimes cannot focus on my daily life. (No. 3)		My main activity is reading books. (No. 3)

as a family. Till date, the daughter-in-law continues to appreciate that experience. Since then, she has resumed collecting picture books, a long-standing hobby, because she could not pursue this endeavour during her mother-in-law's illness. When the daughter-in-law was young, she wished to become a librarian. Since then, she has continued to borrow picture books to read. At present, she is at last able to meet and talk to acquaintances who share her hobby of picture books.

Case no. 8 was a husband who cared for his sick wife. While his wife was fighting her illness, he decided to not tell her about the disease and was committed to spend her remaining time together. His wife wrote about her feelings of gratitude towards the people around her. The husband also filled several notebooks with details of his wife's life and the events of her illness, while reflecting on her life. After her death, the husband wrote a book detailing his wife's last years. This book was meant to be a memorial to his wife that would offer a glimpse of his role as a husband as well as his time with his wife and family. The book described his wife's state of mind while she was fighting her illness and included calligraphy that they had completed together, which reflected the couple's journey. At present, the husband has resumed his former hobby of photography, which he was unable to pursue during his wife's illness. He travels in a friend's car to capture pictures of mountains and neighbourhood scenery, which are shown in an annual exhibition. He has also received some awards.

3) 'Work is insufficient': case nos. 3, 4 and 9

Case no. 3 was a wife who cared for her sick husband. One day, her husband visited a hospital because of severe fatigue. After the doctor diagnosed him with

cancer, his wife chose to remain a driving force in his life. She and other family members provided in-home palliative care for a period of 14 days. During that time, the wife spent time with her husband by getting involved in his favourite activities. She continued to encourage him to participate in every activity as well as he could. At the same time, she continued to organise a resume for their printing business believing that he would completely recover. He never gave up trying to recover from cancer, and although he desperately fought and faced his illness, he unfortunately passed away. After his death, his wife closed the printing business and lived at home, choosing to not work any longer. Till date, she sometimes finds it difficult to resume her normal life. The only activities that sustain her are reading and the memory of what her husband said to her while he was fighting his illness: 'I married you and wanted us both to be happy'.

Case no. 4 was also a wife who cared for her sick husband. While the husband was fighting his illness, his family members were united and supported his endeavours and needs by accompanying him during his drives to the hospital, workplace and home. During these car rides, they reflected on and talked about their family life together, while travelling and walking. In addition, when home palliative care began, the wife expressed a particular fondness for the dining table that had given them a place to enjoy familial interactions. While he was fighting his illness, the husband and wife enjoyed gardening activities such as pruning plants together. The wife stated that she would organise her own state of mind while exchanging emails with her friends and hoped that her husband would continue to fight his illness the following day. Immediately after her husband died, she said, 'It was great that our whole family cared for him together'. After that, she continued to eat with her family members around the dining table and offered them flowers from the garden. Moreover, till date, she continues to exchange emails with her friends, which was a former hobby that she enjoyed before her husband died.

Case no. 9 was a grandchild who cared for her sick grandfather. While the grandfather was fighting his illness, no one told him that he had cancer. Moreover, the grandmother devotedly cared for her husband, although there were times when she broke down in tears when leaving the hospital. Following this, since no therapeutic effect was expected, in-home palliative care was commenced. As a goal of this in-home palliative care, the family planned to visit a field that the grandfather loved. However, as the grandfather's physical strength was rapidly deteriorating owing to worsening pathology, they were unable to travel. Even then, the grandmother continued to care for her husband with the hope that he may be able to visit the field at another time. At that time, one of their grandchildren experienced extreme stress, became emotionally exhausted and was incapable of caring for her grandfather any further. Shortly thereafter, the grandchild's mother was also diagnosed with terminal cancer. Although the mother was aware of her cancer, she cared for the grandfather through his final days. After the grandfather died, all his family members reported feeling like 'empty shells'. The situation got so out of control that the family members stopped getting along with each other. The grandchild became distressed over her family's situation, which had fallen apart, and even considered suicide to join her grandfather. Even after the grandfather's death, the grandmother continued to work quietly on the field that he had loved. Three years after his death, the grandchild got married and had a child, which reunited the family.

Considerations

Occupation was categorised into 3 types: (i) continued, (ii) resumed and (iii) interrupted. Based on these categories, we examined the impact that the occupational performance patterns and the occupation of families of patients with terminal cancer had on alterations in the mental state as follows:

[Occupation continued type] Activities such as gardening, birthday parties, conversations, dining and leisure activities enjoyed with the patients with cancer as they fought their illnesses was a factor in promoting communication. These occasions provided social opportunities for families of patients with cancer, who tended to become absorbed in providing care, and offered opportunities to ameliorate stress [10]. In addition, continuing such occupation after the patients' death lessened excessive grief and the feeling of sudden change. The immediate family's image appeared to remain unbroken in the minds of other family members, and the increased improvement in grief suggested that these activities contributed to strengthening familial relationships. Furthermore, it is thought that the experience of working together with others in various ways such as writing a diary, taking pictures, or writing a songbook (not only during but also after the battle with illness) helped family members to embrace their feelings. In a report on family and social functions and other activities that provide family members with a sense of identity and purpose, Keesing et al. [11] noted that after the death of a family member, looking back to the occupaton of planning the memorial service and otherwise expressing their feelings appears to help the family members sort out their feelings.

[Occupation resumed type] The hobbies and interests that the families of patients with terminal cancer gave up while the patient was fighting against the illness were resumed after the patient's death. During the illness, caregiving for the patient was the highest priority; thus, hobbies and interests were abandoned. However, as they were no longer required to provide care after the patient's death, former hobbies and interests could be resumed. Words of gratitude from the patients before death often served as a trigger for the resumption of past hobbies and interests, along with a sense of accomplishment from having provided in-home care to the patient. To have the opportunity to resume a former hobby, the family member must be able to resume occupation at any time [12]. In other words, when abandoned activities that had formerly been performed on a daily basis were resumed, it offered some respite to the family members after the patient's death, which suggested an opportunity to promote a sense of closure.

In the 'occupation interrupted type', family members of patients with terminal cancer were dedicated to caring for the patients with the hope of recovery. However, such care was not rewarded and these hopes did not come true. In such cases, the bond between the family members and patients does not always become stronger through occupation during the illness. In addition, there are no comforting memories of the caregiving experiences to aid in alterations in the mental state after death. For them, everything is lost. The resulting long-term unexpected loss of occupational deprives the family members of something that is necessary for a person to survive [13−15]. Therefore, we believe that we need to provide people with occupation that can connect these patients with their families before death, as a form of occupational therapy. Pickens and Pizur-Barnekow [16] referred to the significance of collaboration as follows: 'People tend to characterise the meaning of life by interacting with each other'. It is thought that facilitating communication through cooperative occupation plays a role in deepening the bonds of patients and their families and characterizing the meaning of the patients' lives. Furthermore, in occupational therapy, it is thought that it is important to propose environmental adjustments so that the families can continue their work even after the patients' deaths [4]. Clark [17, 18] pointed out that occupation plays a central role in the existence of human beings and adds meaning to life. It has been suggested that offering work to family members provides the opportunity to prepare for and confront grief even after the patients' deaths [4].

Future challenges and limitations

We believe that it is necessary to further elucidate occupational performance patterns, including pathological grief, experienced by families of patients with terminal cancer. Moreover, to confirm the generalizability and robustness of this model, it is necessary to perform further analysis in a quantitative study design and to measure triangulation. To achieve proper understanding of such situations, it is necessary to implement a research design with qualitative and quantitative measures.

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■ORIGINAL ARTICLE

The characteristics of the pencil grip of 6−7-year-old children in Japan

Satoshi Sasada

School of Rehabilitation, Kanagawa University of Human Services

Abstract: The purpose of this study is to clarify the patterns of 6−7-year-old children's pencil grip in Japan, and to clarify the relationship between grip pattern and gender. The participants were 80 first graders in the regular class of an elementary school (40 boys, 40 girls). Of the 80 children, 20 percent implemented a standard pencil grip. Additionally, 60 percent of the children held their pencil with three fingers, and 70 percent held their pencil near the tip. Analyses were conducted to determine factors related to gripping the pencil near the tip, and this practice was found to significantly differ with respect to thumb IP joint flexion. There was no significant difference regarding the position of the thumb, gender, and the number of fingers that touch the pencil. The data revealed that about 20 percent of 6- and 7-year-old children implemented an average pencil grasp.

Keywords: pencil grip, handwriting, position of holding a pencil

(*Asian J Occup Ther* **12**: 37−41, 2016)

Introduction

In Japan, the educational system for children with physical and mental disabilities was converted from "Special Education" to "Special Needs Education," starting in 2001. Ministry of Education, Culture, Sports, Science and Technology (MEXT) [1] is described as follows. Formerly, special schools had been established separately by type of disability, such as "Schools for the Blind," "Schools for the Deaf," and "Schools for the Intellectually Disabled, the Physically Disabled and the Health Impaired." However, the number of children with multiple disabilities has been increasing, and in order to appropriately meet their needs, the School Education Law was partially amended and enacted in 2007. Under the new "Schools for Special Needs Education" system, one particular school can accept children with several types of disabilities. "Special Needs Education" is for students with disabilities, in consideration of their individual educational needs; it aims to fully develop each child's capabilities, independence, and social participation. "Special Needs Education" is carried out in various forms, including resource rooms and special classes within regular schools, and in special schools named "Schools for Special Needs Education." "Special Needs Education" provided in regular schools serves children with many disabilities, including speech impairments, autism, emotional disturbances, low vision, hearing impairments, learning disabilities (LD), and attention-deficit/hyperactivity disorder (ADHD). With the "Special Needs Education" system, research in school-based occupational therapy settings has increased [2, 3]. Handwriting is indicated as an example of a topic requiring consultation between occupational therapists and teachers [4, 5]. From the author's experience, requests from teachers for occupational therapy services for handwriting involved more boys than girls. This is due to the fact that many boys are writing characters by gripping the point of the pencil. As was exhibited in a previous study, there is research that has analyzed how typical children and children who exhibit a developmental delay hold a pencil [6−15]. There are, however, few prior studies in occupational therapy that involve how a Japanese child should hold a pencil [16, 17]. Therefore, the purpose of this study is to clarify the pattern of pencil grip of children from 6- to 7 years old in Japan, and to clarify the relationship between grip pattern and gender. This study also seeks to obtain fundamental data for developing a handwriting intervention program in

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Corresponding to: Satoshi Sasada, School of Rehabilitation, Kanagawa University of Human Services, Heiseicho 1-10-1, Yokosuka City, Kanagawa Prefecture, Japan
e-mail: sasada@kuhs.ac.jp
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Japan.

Method

Participants

The participants were 80 first graders from the regular class of an elementary school (40 boys, 40 girls). The age range was from 6- to 7 years old. Consent for research was obtained from the school's principal and teachers.

The criteria for pencil grip

The criteria for optimal pencil grip were based on the model in a Japanese textbook, and are shown in Fig. 1.

- Three fingers are used to hold the pencil.
- These are the thumb, index finger, and middle finger.
- The pulp of the thumb presses down on the pencil.

Hold position (distance from pencil tip)

When the hold position was 1 inch from the tip of the pencil, it was judged as being suitable. Two unsuitable hold patterns were also identified. If the cone part of the pencil was held, it was judged as proximity. When the pencil was held from the core at more than 1 inch from what is considered suitable, it was judged as distality (Fig. 2).

Protocol

Each child sat in a chair and wrote a line on A4 paper with a pencil. As the children wrote, each child's hand was photographed with a digital camera.

Survey Items

The following aspects were noted for each child during the handwriting task:

1) The number of fingers holding the pencil
2) The position of the fingers holding the pencil
3) The position of the thumb on the pencil

- The position of the thumb was checked, and it was noted whether or not the pulp of the thumb pressed down on the pencil.
- It was also noted whether the angle of the IP joint of the thumb was flexed too much.

Two therapists, employing the above criteria, analyzed each photograph to determine whether the standard pencil grip was used.

Statistical analysis

The number and rate were computed for each item. A chi-squared test and multiple linear regression were applied to the data.

Results

Grip pattern and gender

As shown in Fig. 3, about 20 percent of the children used a standard pencil grip.

A non-standard pencil grip was observed in almost 80 percent of the children, regardless of gender (Figs. 4 & 5).

There was no significant difference between boys and girls in regard to pencil grip ($\chi^2(1) = .478$, ns).

Three- and four-finger grip

Sixty-two percent of the children held the pencil with three fingers (Fig. 6).

More girls than boys gripped the pencil with four fingers (Figs. 7 & 8).

The use of a three- versus four-finger grip did not significantly differ between genders ($\chi^2(1) = .471$, ns).

Position of fingers holding the pencil

Seventy-four percent of the children gripped near the tip of the pencil (Fig. 9).

The position of the fingers did not significantly differ with respect to gender ($\chi^2(2)= 1.898$, ns). The

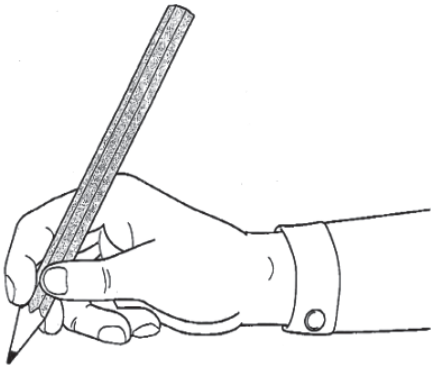

Fig. 1. The standard way to hold a pencil.

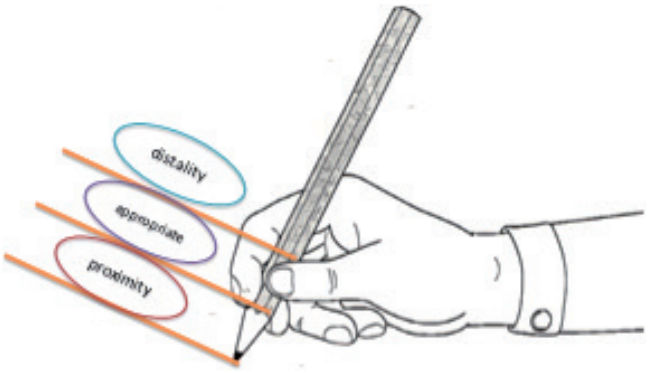

Fig. 2. The position of the fingers of holding the pencil.

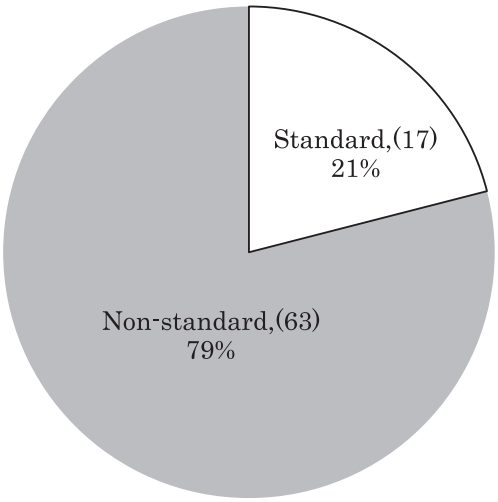

Fig. 3. Pattern of pencil grip (n = 80).

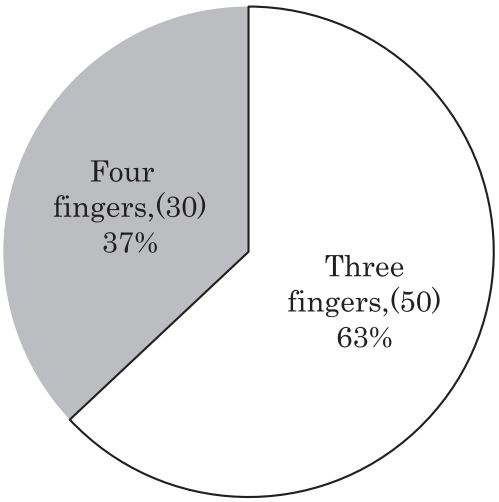

Fig. 6. Number of fingers used to hold pencil (n = 80).

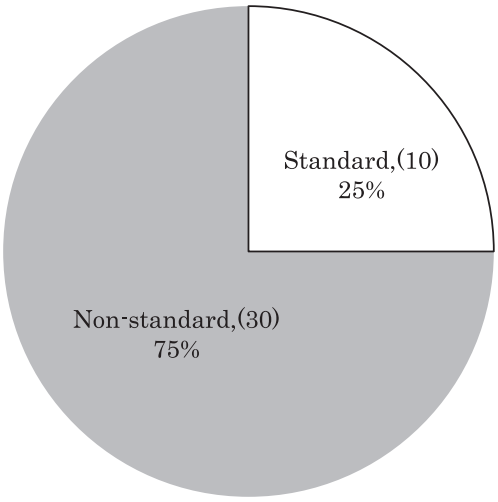

Fig. 4. Pattern of pencil grip for girls (n = 40).

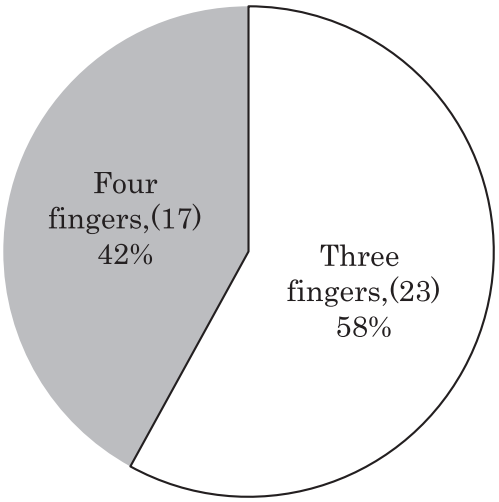

Fig. 7. Number of fingers used to hold pencil for girls (n = 40).

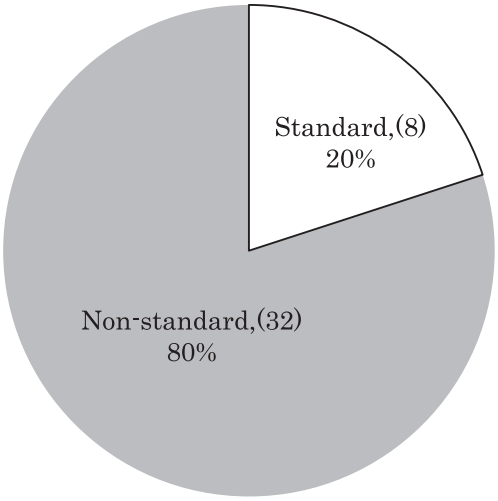

Fig. 5. Pattern of pencil grip for boys (n = 40).

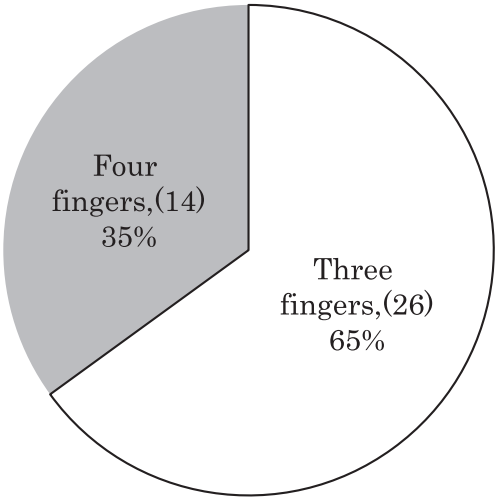

Fig. 8. Number of fingers used to hold pencil for boys (n = 40).

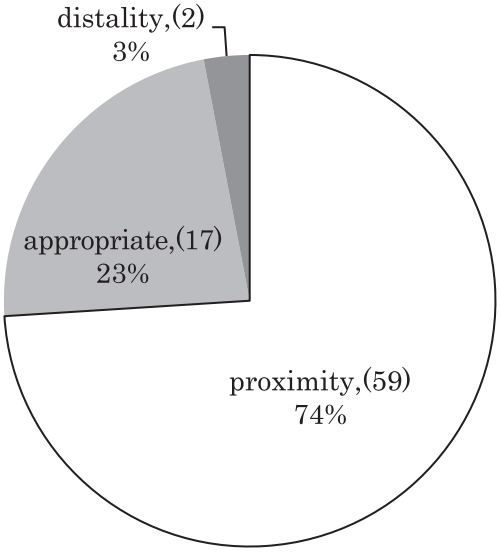

Fig. 9. Distance of fingers touching pencil (n = 80).

frequency of holding a pencil too close to the tip did not significantly differ in regard to the position of the thumb, gender, and the number of the fingers touching the pencil. However, it significantly differed with respect to thumb IP joint flexion ($p < .05$).

Position of the thumb

The position of the thumb did not significantly differ with respect to the number of fingers touching the pencil ($\chi^2(1) = 1.083$, ns).

Discussion

For the first grader, handwriting is a skill that must be mastered [18]. Regarding the relationship between pencil grip and gender, anecdotally, it appears that boys are more likely than girls to exhibit an immature pencil grip. During the course of this study, it was observed that the rate of girls exhibiting the correct pencil grip was slightly higher than that of boys. When analyzed statistically, however, the data revealed that pencil grip and gender are not related. Pencil grip, therefore, cannot be judged by gender in the sense that "boys have a tendency, more so than girls, toward exhibiting an immature pencil grip." We need to warn school personnel and others against judging an awkward pencil grip as simply a gender difference. Regarding the developmental progression of pencil grip, 3−4-year-old children use a static 3-finger grip, and gain a dynamic 3-finger grip by 4- to 5 years. Therefore, it seems logical to assume that most children should have mastered the 3-finger pencil grip by the age of 6 or 7 years. However, the data revealed that only 21% of the children studied were implementing the dynamic three-finger grip, which was a low rate compared to what was expected. As is shown in Fig. 6, about 40 percent of the children held the pencil using four fingers; these children were not fully capable of holding the pencil with three fingers. Schneck and Henderson [7] point out that about six- to seven-tenths of 6-year-olds use a dynamic three-finger grip. On the other hand, the dynamic three-finger grip is not used among 6- to 7-year-old children. It is speculated that the three-finger and four-finger grips are intermingled among 6- to 7-year-old children. Factors related to holding a pencil near the tip were not clarified in this research. Future studies should investigate conduct longitudinal investigations from the first to sixth grade. About 70 percent of the children were holding the pencil too close to the tip. This shows that the child is writing such that the characters and the fingers are very near. Proximal hold of the pencil was related to bending the IP joint of the thumb. This is due to the fact that when the cone part of a pencil is held, in order to write well, children have to press down on the cone part by the finger pad of the thumb. Furthermore, the child may lean the body in order to write a character,. It is said that it has a pencil in 1 inch of distance from the core of a pencil [19]. But, the influence by hold of the cone part of a pencil is not described. A limitation of this research is that it was not able to clearly describe the relationship between grip method and posture. Handwriting is influenced by not only finger motion but also the position of the trunk and legs. Therefore, for future research, it is necessary to investigate the relationship between the method of gripping a pencil and body posture.

Acknowledgement: The author thanks the children who cooperated with this study, as well as the school officials.

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■ORIGINAL ARTICLE

Development of a task-specific occupational therapy training menu for the improvement of upper limb function in stroke patients

Kunji Shirahama[1], Masatoshi Gocyou[2], Tomomi Morita[3], Taeko Kitahashi[4], Tomonori Yasuda[5]

[1] Kanagawa University of Human Service, Faculty of Health & Social Services, School of Rehabilitation, Division Occupational Therapy
[2] Kawasaki Rinko General Hospital
[3] Shonan Central Hospital
[4] IMS Itabashi Rehabilitation Hospital
[5] Kumamoto Health Science University

Abstract: Rehabilitation for stroke patients requires a large amount of high-quality, intensive training. However, for most patients, use of the paralyzed upper limb is avoided in daily life outside of rehabilitation therapy. The purpose of this study was to devise a menu of tasks for improving upper limb function in patients with hemiplegia after stroke. Participants included 39 occupational therapists with experience in treating patients with hemiplegia after stroke. The tasks were organized and rewritten as 26 items on a questionnaire. Participants were asked to consider the tasks for inclusion in the upper limb function task menu. The participants identified the lowest possible Brunnstrom recovery stage (BRS) for the upper limb and fingers required to complete each task. In accordance with the Delphi method, this study was conducted in three rounds. The final round included 32 occupational therapists with an average of 4.40 ± 3.00 years of experience. The mean score (±SD) for evaluation of the tasks in this round was 3.85 ± 0.63 and the median value was 3.85. The same mean value of 3.0 was chosen to represent recommendation to adopt a task. In the final round, 100.0% (26/26) of the tasks were selected for adoption. The mean value (±SD) for the lowest BRS for the paralyzed upper limb was 4.26 ± 0.41 (median, 4.15) and that for the fingers was 4.57 ± 0.46 (median, 4.62). Results indicated that these tasks would be useful for upper limb functional training for stroke patients. The most important aim of occupational therapy is to make patients aware of what movement is possible. The role of occupational therapists is to provide task-specific training by using a feasible upper limb function task menu that demonstrates ability to improve upper limb function in patients undergoing occupational therapy after a stroke.

Keywords: task specific training, training menu, stroke

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Introduction

Stroke rehabilitation for patients with hemiplegia after stroke involves incorporation of facilitation techniques. Traditional neurological treatment approaches have been used to construct an efficacious motor recovery intervention strategy [1]. However, meaningful task-specific programs (such as reaching for an object that is presented) are reportedly more effective than therapy using these traditional approaches [2]. Furthermore, rehabilitation after stroke is intensive; however, functional training using range of motion exercises and specific facilitation techniques involves only passive participation. Task-specific therapeutic intervention provides practical, daily behavioral training in which positive changes can actually be experienced. Currently, there are a number of reports involving various rehabilitation approaches after stroke [3], including virtual reality-based rehabilitation systems [4]. Rehabilitation for stroke patients requires a large amount of high-quality intensive training [5]. Patients undergoing intensive

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Corresponding to: Kunji Shirahama, Kanagawa University of Human Service, Faculty of Health & Social Services, School of Rehabilitation, Division Occupational Therapy, 1-10-1, Heiseicho, Yokosuka, Kanagawa, 238-8522, Japan.
e-mail: shirahama-k@kuhs.ac.jp
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training received at least 16 hours more treatment time in the first 6 months after stroke compared to patients receiving traditional therapies [6], and the amount of training was increased incrementally each day [7]. However, in most cases, the frequency of use of the paralyzed upper limb is extremely low in patients with hemiplegia after stroke, and use of the paralyzed hand is avoided in daily life outside of rehabilitation therapy.

The feasibility of use of high repetition exercises (reaching, grasping, manipulating, transporting, and releasing) as part of a task-specific approach has been reported in investigations involving therapies that are different from those currently delivered in routine clinical practice [8]. This new rehabilitation strategy was developed based on the results of animal experiments [9] and human motor learning and psychology studies [10]. The task-specific approach focuses on repeated practice of tasks in which the subject is conscious of specific learning objectives and has strong motivation to improve functional performance. This training method involves focusing on the performance of specific tasks. It is superior to simple, repetitive practice of mechanical actions, such as flexion of the elbow joint, which have been shown to have no effect on functional performance and/or cortical reconstruction [11, 12]. Performing specific tasks for the purpose of rehabilitation aids functional recovery in the upper limbs, affects brain activation patterns [13], and facilitates functional reconstruction of the cortex [14].

The effectiveness of constraint-induced movement therapy (CI therapy) for upper limb functional training after apoplexy has been widely reported [15]. Rehabilitation therapy can involve combining CI therapy with the task-specific approach and other intervention methods. Eating, grasping, using a spoon, and picking up objects [16] have been among the tasks utilized in this approach. However, voluntary extension of the wrist joint and fingers is an adaptive criterion in CI therapy; thus, the application of this special therapy is limited to subjects with mild paralysis. Furthermore, CI therapy constrains the non-paralyzed limb, which raises concerns about ethical issues and may increase stress on patients.

On the other hand, task-specific therapy involves repetition of multiple tasks. Significant functional improvement in the paralyzed upper limb was observed after repetition of eight different tasks [17], cortical reconstruction was seen after performance of six different tasks [18], and reconstruction of the activation site was seen after performance of a tracking task [19]. In addition, intensive performance of task-specific training associated with activities of daily living reportedly changes cortical activity [20]. Finally, task-specific upper limb functional training has an effect on restructuring and restoration of brain function.

Therefore, the purpose of this study was to devise a task menu for improving upper limb function for therapeutic purposes for use in treatment of patients with hemiplegia after stroke. This upper limb function task menu was designed to include tasks that could be performed with daily items.

Methods

Participants

The participants included 39 occupational therapists from nine hospitals with experience in treating patients with hemiplegia after a stroke.

In this research, the subjects were selected by snowball sampling from among occupational therapists belonging to the Japanese Association of Occupational Therapists.

Sample size

In order to detect significant differences within our data, it was necessary to calculate the sample size required for the chi square test. We determined that we needed a minimum sample size of 32 to satisfy the following conditions: a significance or alpha (α) level of 0.05, a statistical power of 0.8, and an effect size of 0.5 (high) [21] by G*power 3 [22]. A total of 39 participants were recruited to compensate for possible dropouts (10% of the estimated sample size).

Questionnaire method

A questionnaire was distributed to the occupational therapists in order to acquire information about tasks that would facilitate improvement of upper limb function in the paralyzed limb in patients with hemiplegia after stroke. This research was conducted between September 2012 and January 2013 in accordance with the Delphi method [23]. The Delphi method is a qualitative research method that merges the opinions of subjects with specialist knowledge in a given field by referring to each subject's views several times.

In this study, we distributed our questionnaire for self-completion by mail. The consensus process required the questionnaire to be completed three times (Rounds 1−3). Thus, the results of previous iterations regarding task-specific training items were adopted or rejected by individual participant members in later iterations based on their ability to review and assess the comments and feedback provided by the other participants. Round 1: In the first round, the questionnaire provided the list of twenty-seven tasks and asked each participant to list as many responses as possible. Round 2: In the second

round, each participant received a second questionnaire and was asked to review the items summarized by the investigators based on the information provided in the first round. Round 3: In the third round, the list of remaining items, their ratings, and items achieving consensus were distributed to the participant. This round provided a final opportunity for participants to revise their judgments (Fig. 1).

The tasks being evaluated for inclusion on the upper limb function training menu were selected from previous studies. The tasks chosen were those whose therapeutic effects had been confirmed in previous studies: arm ability training, or AAT [17], task-oriented training, or TT [18], shaping tasks from CI therapy [24], and tracking training [19]. We reorganized the adoption criteria from the 80 tasks into the following categories: AAT: 8 tasks, TT: 6 tasks, Tracking tasks: 1 task, Shaping tasks: 60 tasks, other: 5 tasks.

Inclusion criteria were the following: the tasks needed to be performed while sitting down, to involve repeated handling of objects, and to use the paralyzed upper limb. In addition, each task had to be performable within a time limit of 1minute.The tasks were organized and rewritten as 26 items on the training menu. Participants were asked to consider the tasks for inclusion in the upper limb function training menu. The tasks required patients to reach the lowest Brunnstrom recovery stage (BRS).

First Round

In the first round, the participants were asked to answer two questions about the proposed tasks to be included in the upper limb function training menu The first question asked the participants to identify the degree of movement ability required to carry out each task (the lowest BRS for the upper limb and fingers; I, II, III, IV, V, or VI). They were then asked to evaluate the appropriateness of each task for use with patients experiencing hemiplegia after a stroke (1: adopted; 2: rejected).

Second Round

For the second round, the results from the first round were mailed to all participants, who also received a newly created training implementation manual. Participants re-examined the tasks with reference to the opinions of other participants from the first round. Because many of the tasks were adopted in the first round, in the second round participants were asked to choose from five options regarding the suitability of the items on the list for inclusion on the upper limb function training task menu. Items were scored on a scale from 5 (very suitable) to 1 (not suitable). Tasks were rated as follows: 1; not suitable, 2; suitability uncertain, 3; somewhat suitable, 4; suitable, 5; very suitable. The results of the second round questionnaire were used to determine that a value of 3 would determine whether the task would be adopted. Other questionnaire items remained unchanged.

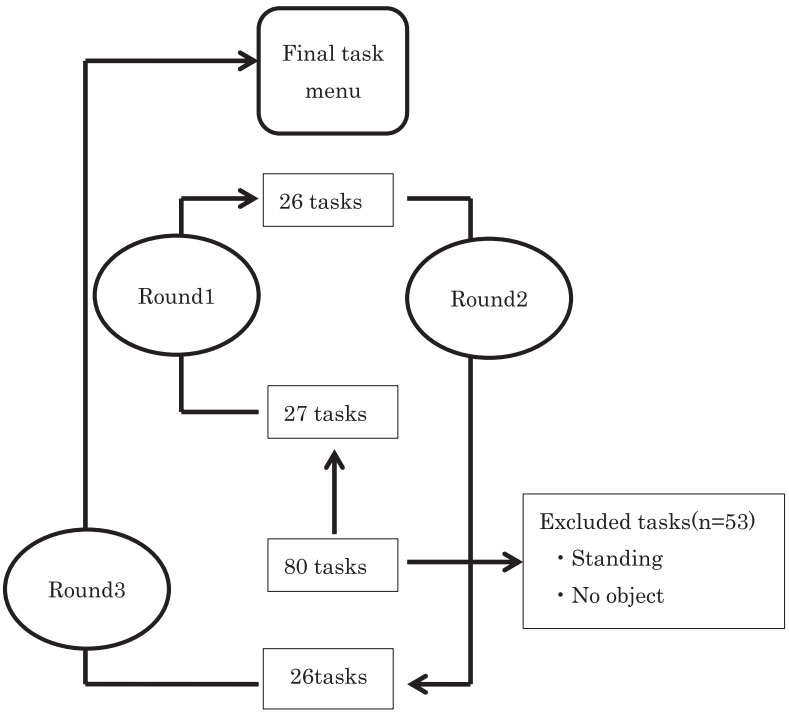

Fig. 1. Delphi method.

Third Round

The third round consisted of the same questionnaire items as the second round, in the same answer format. Participants re-examined the list of upper limb function training tasks with reference to the opinions of the other participants from the second round.

Analytical methods

Scores were obtained for all tasks in all three rounds. Mean values, standard deviations (SD), and median values for adoption or rejection of tasks and the lowest BRS required for the upper limb and fingers were calculated and analyzed. The task evaluation score data were statistically analyzed using the binomial test. Statistical analysis was performed using SPSS version 20.0. In all analyses, $p < 0.05$ was considered statistically significant.

Ethical considerations

Written explanations were mailed to all participants regarding the purpose of the study. Participation was voluntary. Participants were informed that withdrawal from the study was permitted at any time. The occupational therapists selected as participants were those who understood the content of the study and gave written consent for participation. Approval for this study was obtained from the Kanagawa University of Human Sciences Research Ethics Committee (approval number: 23-045).

Results

The number of participants in the survey

In the first round, 34 participants (87% response rate, 13 men and 21 women) with an average of 4.35 ± 2.66 years of experience (mean ± SD) completed the questionnaire. The second round included 33 participants (97% response rate, 13 men and 20 women) with an average of 4.38 ± 2.62 years of experience. The third round included 32 participants (97% response rate, 12 men and 20 women) with an average of 4.40 ± 3.00 years of experience.

Task evaluation

First Round

In the first round, participants decided either to adopt (1 point) or reject (2 points) the upper limb function training tasks from the list provided in the questionnaire. The mean value (± SD) for the 26 items was 1.11 ± 0.09 and the median value was 1.10. Of the 26 items, 24 (92.31%) were scored between 1.00 and 1.25, and two items (7.69%) were scored between 1.26 and 1.50. Thus, in the results of the first round, most participants chose to adopt the listed tasks.

Second Round

In the second round, the mean score (± SD) for the evaluation of task suitability was 3.79 ± 0.39 and the median value was 3.86. Scores between 4 and 5 were recorded for 38.46% of the items (10/26), while scores of between 3 and 4 were recorded for 57.69% of the items (15/26) and scores between 2 and 3 were recorded for 3.58% (1/26). The mean cutoff score of 3 was chosen to represent recommendation to adopt the item on the task menu. Thus, 96.15% (25/26) of the tasks on the list were selected for adoption. The task that was not adopted was "flipping a switch."

Third Round

The third round consisted of the same questionnaire items and answers as the second round. The mean score (± SD) for evaluation of the tasks in this round was 3.85± 0.63 and the median value was 3.85. Scores of between 4 and 5, between 3 and 4, and between 2 and 3 were recorded for 38.46% (10/26), 61.54% (16/26), and 0% (0/26) of the items, respectively. In the third round, 100.0% (26/26) of the tasks were selected for adoption (binominal test, $p < 0.05$). In all, 79 (100%) of the tasks were adopted, since they received an evaluation score of 3 or more. The tasks were listed in Table 1 and Table 2 shows detailed results.

The task evaluation score data were statistically analyzed using the binomial test (Table 3). There were statistically significant differences in adoption rates.

Lowest BRS

First Round

In the first round, the mean value (± SD) for the lowest BRS for the paralyzed upper limb was 4.40 ± 0.58 and the median value was 4.27. The lowest BRS ratings of IV–V were observed for 96.15% of items (25/26), and ratings of III–IV were recorded for 3.85% (1/26). For the fingers, the mean value (± SD) for the lowest BRS was 4.62 ± 0.63 and the median value was 4.67. The lowest BRS ratings of V–VI were observed for 19.23% of items (5/26), while 76.92% were rated IV–V (20/26), and 3.85% were rated II–III (1/26). The lowest BRS rating of IV or above accounted for the majority of the items requiring use of both the upper limbs and fingers.

Second Round

In the second round, the mean value (± SD) for the lowest BRS for a paralyzed upper limb was 4.31 ± 0.48 and the median value was 4.15. The lowest BRS ratings of IV–V were observed for 96.15% of items (25/26) and ratings of II–III were seen for 3.85% (1/26). The mean value (± SD) for the lowest BRS for the fingers was 4.60 ± 0.55 and the median value was 4.65. The lowest BRS ratings of V–VI were observed for 23.08% of items

Table 1. Tasks list.

1	Pick up bean bags and lift them to your mouth, then place them on the table
2	Wipe a bowl with a cloth
3	Pick up clips and place them in a container
4	Solve computational problems on a calculator
5	Pick up five of one, five, and 10 yen coins and place them in a box
6	Pick up small iron balls and place them in a container (2 types: 1.2 cm and 0.6 cm)
7	Draw hiragana, numbers and shapes
8	Flip switches
9	Fasten acrylic sheets together from different angles with clothes pegs
10	Wipe a table back and forth with a towel or place your forearm on a towel and move it back and forth and in circles
11	Fold a bath towel
12	Trace a 20-cm diameter circle clockwise and anti-clockwise with your index finger
13	Go through a maze with your index finger
14	Go through a maze with a pen
15	Stack Jenga blocks
16	Turn over and stack playing cards
17	Cut paper with scissors following a maze
18	Create a knot (a bow) and untie it
19	Move and stack four plastic cups
20	Reach for and grab plastic bottles, then move them. Unscrew and close the cap.
21	Pick up pens and place them in a penholder
22	Line cancellation test
23	Pick up tennis ball s and place them in a container
24	Roll tennis balls around on a tray without dropping them
25	Unscrew, take them apart, and tighten three types of bolts and nuts
26	Turn the page of a book

Table 2. Task evaluation.

Task	Round 1		Round 2						Round 3					
	1: adopt; 2: reject	adop (%)	1: not suitable, 2: suitability uncertain, 3: somewhatsuitable, 4: suitable, 5: very suitable.					over3 (%)	1: not suitable, 2: suitability uncertain, 3: somewhatsuitable, 4: suitable, 5: very suitable.					over3 (%)
	dopt		1	2	3	4	5		1	2	3	4	5	
1	32	94.1	0	1	6	16	10	97	0	0	2	23	8	100
2	33	97.1	0	0	6	20	7	100	0	0	2	24	7	100
3	30	88.2	0	3	8	18	4	91	0	0	5	24	4	100
4	26	76.5	1	7	14	9	2	76	1	0	24	7	1	97
5	33	97.1	0	2	3	19	9	94	0	0	2	26	5	100
6	30	88.2	1	5	7	17	3	82	0	1	7	23	2	97
7	31	91.2	1	1	4	19	8	94	0	0	7	21	5	100
8	25	73.5	7	7	8	11	0	58	0	4	24	4	1	88
9	34	100.0	0	0	3	23	7	100	0	0	4	24	5	100
10	33	97.1	0	0	2	15	16	100	0	0	2	22	9	100
11	31	91.2	0	0	5	20	8	100	0	0	2	25	6	100
12	28	82.4	1	3	10	17	2	88	0	3	12	17	1	91
13	27	79.4	1	5	5	19	3	82	0	1	12	20	0	97
14	28	82.4	1	5	6	16	5	82	0	2	9	20	2	94
15	31	91.2	0	4	8	17	3	85	0	0	7	21	5	100
16	31	91.2	0	2	5	21	5	94	0	0	5	26	2	100
17	30	88.2	1	4	5	18	5	85	0	1	6	21	5	97
18	34	100.0	0	0	5	18	10	100	0	0	4	21	8	100
19	29	85.3	0	0	7	18	8	100	0	0	4	23	6	100
20	33	97.1	0	1	2	17	13	97	0	0	1	23	9	100
21	33	97.1	0	2	6	20	5	94	0	1	4	24	4	97
22	25	73.5	1	9	13	9	1	70	0	7	20	5	1	79
23	33	97.1	0	0	7	20	6	100	0	0	7	23	3	100
24	27	79.4	1	2	7	18	5	91	1	0	8	23	1	97
25	34	100.0	1	2	7	18	5	91	0	0	5	26	2	100
26	33	97.1	0	2	3	23	5	94	0	0	2	25	6	100

Table3. A Statistical analysis of task evaluation

Task	Ave	SD	Median	P
1	4.22	0.58	4.00	< 0.001
2	4.15	0.60	4.00	< 0.001
3	3.96	0.59	4.00	< 0.001
4	3.22	0.75	3.00	< 0.001
5	4.11	0.51	4.00	< 0.001
6	3.74	0.66	4.00	< 0.001
7	3.93	0.68	4.00	< 0.001
8	3.07	0.68	3.00	< 0.001
9	4.04	0.59	4.00	< 0.001
10	4.30	0.61	4.00	< 0.001
11	4.15	0.53	4.00	< 0.001
12	3.37	0.74	3.00	< 0.001
13	3.48	0.58	4.00	< 0.001
14	3.59	0.75	4.00	< 0.001
15	3.93	0.68	4.00	< 0.001
16	3.89	0.51	4.00	< 0.001
17	3.89	0.75	4.00	< 0.001
18	4.15	0.66	4.00	< 0.001
19	4.07	0.62	4.00	< 0.001
20	4.33	0.55	4.00	< 0.001
21	3.93	0.68	4.00	< 0.001
22	3.00	0.78	3.00	< 0.02
23	3.85	0.60	4.00	< 0.001
24	3.63	0.74	4.00	< 0.001
25	3.89	0.51	4.00	< 0.001
26	4.11	0.58	4.00	< 0.001

(6/26), 73.07% were rated IV–V (19/26), and 3.85% were rated III–IV (1/26). The lowest BRS ratings of IV or above accounted for the majority of items that had been considered suitable according to the results of the questionnaire. The only lower-rated task that had been considered suitable was the towel task (BRS < IV).

Third Round

In the third round, the mean value (± SD) for the lowest BRS for the paralyzed upper limb was 4.26 ± 0.41 and the median value was 4.15. The lowest BRS ratings of IV–V and III–IV were observed for 96.15% (25/26) and 3.85% (1/26) of the items, respectively. The mean value (± SD) for the lowest BRS for the fingers was 4.57 ± 0.46 and the median value was 4.62. The lowest BRS ratings of V–VI were observed for 7.69% of items (2/26), 80.77% were rated IV–V (21/26), 3.85% were rated III–IV (1/26), and 3.85% were rated II–III (1/26). Tables 4 and 5 give the detailed results for our study.

Discussion

In this study, three rounds of questionnaire administration were conducted using the Delphi method. The occupational therapists participating in the study were asked to evaluate tasks for improving upper limb function for inclusion in a task-specific approach to treatment of patients with hemiplegia after stroke. The results indicated that many occupational therapists chose to adopt the upper limb function tasks listed in the questionnaire as possible therapeutic techniques.

Task evaluation

The 26 tasks investigated in this study were used in previous studies. However, the reason why these tasks were adopted was not clear, for there were no inclusion criteria given. These studies [17−19, 24] do not describe how the tasks were selected for treatment of stroke patients. In our study, the participating occupational therapists determined the tasks to be appropriate according to inclusion criteria. Our results indicated that there were statistically significant differences.

Among the 26 tasks, less than 90% of replies indicated that the switch task and the line cancellation test should be adopted. The switch task is the only task involving an “ON/OFF” switch, which probably led to the determination that this task was too simple. On the other hand, the line cancellation test requires use of a pen and was determined to be difficult for stroke patients. In addition, the score for the calculation tasks (No. 4), and the task involving tracing a circle or a maze with the index finger (No. 12 and No. 13) often received a score of 3 (somewhat suitable). The calculation task is difficult because it requires complex movements of the finger that are difficult for stroke patients; on the other hand, the tracking task involved gross motor movement.

Most of the tasks were deemed suitable for task-specific upper limb function training in all three rounds. This suggests that these tasks would be useful for upper limb function training for stroke patients.

Lowest BRS

The occupational therapists judged the 26 tasks listed in the questionnaire to be suitable for rehabilitation of patients with moderate to mild paralysis (BRS IV–VI). However, these tasks were deemed unsuitable as part of a training program for patients with severe paralysis [24]. Inclusion of CI therapy shaping tasks in the list may have influenced these results. CI therapy shaping tasks are considered suitable for stroke patients with mild paralysis of the upper limb and fingers. In addition, task-specific upper limb function training involves moving items repeatedly, which requires a certain amount of dexterity to reach out for and handle objects. Further study is required regarding selection of suitable tasks for stroke patients with low BRS.

The need for repetitive training

Many of the 26 tasks in this study were determined by our participating occupational therapists to be appropriate for a stroke rehabilitation program. All of the

Table 4. Lowest BRS (U/E).

Task	Round 1					Round 2					Round 3				
	Ave	SD	Median	Max	Min	Ave	SD	Median	Max	Min	Ave	SD	Median	Max	Min
1	4.03	0.58	4.00	5.00	3.00	4.15	0.44	4.00	5.00	3.00	4.07	0.27	4.00	5.00	4.00
2	4.35	0.65	4.00	5.00	3.00	4.31	0.47	4.00	5.00	4.00	4.30	0.47	4.00	5.00	4.00
3	4.32	0.59	4.00	5.00	3.00	4.06	0.25	4.00	5.00	4.00	4.04	0.19	4.00	5.00	4.00
4	4.24	0.75	4.00	5.00	2.00	4.32	0.48	4.00	5.00	4.00	4.19	0.48	4.00	5.00	3.00
5	4.44	0.50	4.00	5.00	4.00	4.28	0.46	4.00	5.00	4.00	4.11	0.32	4.00	5.00	4.00
6	4.44	0.50	4.00	5.00	4.00	4.25	0.44	4.00	5.00	4.00	4.07	0.27	4.00	5.00	4.00
7	4.50	0.71	5.00	6.00	2.00	4.35	0.49	4.00	5.00	4.00	4.30	0.54	4.00	5.00	3.00
8	4.13	0.57	4.00	5.00	3.00	4.10	0.31	4.00	5.00	4.00	4.04	0.19	4.00	5.00	4.00
9	4.79	0.54	5.00	6.00	3.00	4.64	0.49	5.00	5.00	4.00	4.59	0.50	5.00	5.00	4.00
10	3.82	0.90	4.00	6.00	1.00	3.76	0.50	4.00	5.00	3.00	3.74	0.53	4.00	4.00	2.00
11	4.39	0.56	4.00	6.00	4.00	4.61	0.50	5.00	5.00	4.00	4.59	0.50	5.00	5.00	4.00
12	4.42	0.50	4.00	5.00	4.00	4.32	0.48	4.00	5.00	4.00	4.07	0.27	4.00	5.00	4.00
13	4.53	0.51	5.00	5.00	4.00	4.45	0.51	4.00	5.00	4.00	4.19	0.40	4.00	5.00	4.00
14	4.63	0.49	5.00	5.00	4.00	4.39	0.50	4.00	5.00	4.00	4.26	0.45	4.00	5.00	4.00
15	4.65	0.54	5.00	6.00	4.00	4.52	0.51	5.00	5.00	4.00	4.63	0.49	5.00	5.00	4.00
16	4.44	0.61	4.00	6.00	3.00	4.34	0.48	4.00	5.00	4.00	4.30	0.47	4.00	5.00	4.00
17	4.69	0.47	5.00	5.00	4.00	4.71	0.53	5.00	6.00	4.00	4.74	0.45	5.00	5.00	4.00
18	4.44	0.56	4.00	5.00	3.00	4.30	0.59	4.00	5.00	3.00	4.37	0.49	4.00	5.00	4.00
19	4.15	0.44	4.00	5.00	3.00	4.24	0.50	4.00	5.00	3.00	4.30	0.47	4.00	5.00	4.00
20	4.50	0.56	4.00	6.00	4.00	4.19	0.40	4.00	5.00	4.00	4.19	0.40	4.00	5.00	4.00
21	4.47	0.51	4.00	5.00	4.00	4.25	0.44	4.00	5.00	4.00	4.26	0.45	4.00	5.00	4.00
22	4.42	0.56	4.00	6.00	4.00	4.26	0.51	4.00	5.00	3.00	4.37	0.49	4.00	5.00	4.00
23	4.21	0.54	4.00	5.00	3.00	4.22	0.42	4.00	5.00	4.00	4.15	0.36	4.00	5.00	4.00
24	4.65	0.66	5.00	6.00	3.00	4.48	0.51	4.00	5.00	4.00	4.48	0.51	4.00	5.00	4.00
25	4.30	0.68	4.00	5.00	2.00	4.34	0.65	4.00	6.00	3.00	4.19	0.48	4.00	5.00	3.00
26	4.41	0.56	4.00	6.00	4.00	4.31	0.47	4.00	5.00	4.00	4.15	0.36	4.00	5.00	4.00

BRS: Brunnstrom recovery stage, stage I = 1, stage II = 2, stage III = 3, stage IV = 4, stage V = 5, U/E: Upper Extremity

Table 5. Lowest BRS (Finger).

Task	Round 1					Round 2					Round 3				
	Ave	SD	Median	Max	Min	Ave	SD	Median	Max	Min	Ave	SD	Median	Max	Min
1	4.06	0.65	4.00	5.00	2.00	4.12	0.42	4.00	5.00	3.00	3.93	0.38	4.00	5.00	3.00
2	4.47	0.61	5.00	5.00	3.00	4.44	0.56	4.00	5.00	3.00	4.37	0.56	4.00	5.00	3.00
3	4.85	0.56	5.00	6.00	4.00	4.69	0.54	5.00	6.00	4.00	4.93	0.27	5.00	5.00	4.00
4	4.67	0.74	5.00	6.00	2.00	5.00	0.37	5.00	6.00	4.00	4.85	0.36	5.00	5.00	4.00
5	5.15	0.56	5.00	6.00	4.00	4.94	0.44	5.00	6.00	4.00	4.89	0.32	5.00	5.00	4.00
6	4.97	0.52	5.00	6.00	4.00	5.03	0.47	5.00	6.00	4.00	4.81	0.40	5.00	5.00	4.00
7	4.91	0.62	5.00	6.00	2.00	4.90	0.47	5.00	6.00	4.00	4.96	0.19	5.00	5.00	4.00
8	4.23	0.97	4.00	6.00	2.00	4.47	0.57	4.00	6.00	4.00	4.26	0.53	4.00	5.00	3.00
9	4.97	0.30	5.00	6.00	4.00	4.85	0.36	5.00	5.00	4.00	4.85	0.36	5.00	5.00	4.00
10	2.56	1.48	2.50	6.00	1.00	2.36	1.25	2.00	5.00	1.00	2.26	1.06	2.00	5.00	1.00
11	4.35	0.85	4.00	6.00	1.00	4.58	0.50	5.00	5.00	4.00	4.48	0.58	5.00	5.00	3.00
12	4.52	0.71	5.00	6.00	2.00	4.55	0.89	5.00	6.00	1.00	4.48	0.51	4.00	5.00	4.00
13	4.56	0.72	5.00	6.00	2.00	4.90	0.47	5.00	6.00	4.00	4.15	1.03	4.00	5.00	1.00
14	4.88	0.49	5.00	5.00	3.00	4.55	0.89	5.00	6.00	1.00	4.81	0.48	5.00	6.00	4.00
15	4.65	0.54	5.00	6.00	4.00	4.70	0.53	5.00	5.00	3.00	4.74	0.45	5.00	5.00	4.00
16	5.00	0.43	5.00	6.00	4.00	5.00	0.36	5.00	6.00	4.00	5.00	0.28	5.00	6.00	4.00
17	5.16	0.45	5.00	6.00	4.00	5.03	0.41	5.00	6.00	4.00	5.00	0.28	5.00	6.00	4.00
18	5.06	0.49	5.00	6.00	4.00	5.00	0.35	5.00	6.00	4.00	4.96	0.34	5.00	6.00	4.00
19	4.18	0.58	4.00	5.00	3.00	4.21	0.48	4.00	5.00	3.00	4.15	0.53	4.00	6.00	3.00
20	4.79	0.73	5.00	6.00	3.00	4.63	0.66	5.00	5.00	2.00	4.78	0.51	5.00	6.00	4.00
21	4.65	0.54	5.00	6.00	4.00	4.69	0.59	5.00	6.00	3.00	4.78	0.42	5.00	5.00	4.00
22	4.94	0.43	5.00	6.00	4.00	4.84	0.45	5.00	6.00	4.00	4.93	0.38	5.00	6.00	4.00
23	4.38	0.65	4.00	5.00	3.00	4.25	0.51	4.00	5.00	3.00	4.15	0.46	4.00	5.00	3.00
24	4.39	0.76	4.00	6.00	2.00	4.32	0.75	4.00	5.00	3.00	4.44	0.64	5.00	5.00	3.00
25	5.00	0.43	5.00	6.00	4.00	5.00	0.51	5.00	6.00	3.00	5.04	0.19	5.00	6.00	5.00
26	4.68	0.64	5.00	6.00	4.00	4.59	0.56	5.00	5.00	3.00	4.74	0.53	5.00	6.00	4.00

BRS: Brunnstrom recovery stage, stage I = 1, stage II = 2, stage III = 3, stage IV = 4, stage V = 5.

following tasks were determined to be appropriate by all of the occupational therapists: beanbags task, wiping the bowl, clip task, the coin task, writing a letter, clothespin task, towel task, bath towel task, Jenga, trump task, string task, cups task, PET bottles task, tennis balls task, and bolts task. However, the usefulness of those specific tasks is limited to patients experiencing the degree of paralysis found in relatively mild stroke patients.

In previous studies, reports demonstrating the effects of task-specific training indicate that a large amount of training must be performed [20]. The benefits of a high intensity program are well established, with the most important benefit being that rehabilitation clinicians provide repetitive task training. It was an important finding that therapies involving high repetition must involve feasible tasks [25]. Repetitive training that includes practice of a particular movement involving achievement of a specific goal during functional task practice may improve specific impairment [26]. The repetitive training is based on the fundamental principle that repeated practice is the best way to learn a particular task [14].

The importance of task training in occupational therapy

Patients may decide that functionality in the limb has permanently declined and that rehabilitation is "not possible." The most important aim of occupational therapy is to make patients aware of what is "possible." The role of occupational therapists is to provide task-specific training using a feasible upper limb function task menu, which may enhance patients' sense of competency and ability to bring meaningful functional gains. A task-specific approach should include a variety of tasks that take individual patient needs into account [27].

However, the practical application and therapeutic effects of upper limb function tasks for stroke patients must be investigated based on the results obtained from this study.

Conclusions

A group of occupational therapists was asked to evaluate upper limb function tasks for inclusion in a repetitive training task menu designed for treatment of patients with hemiplegia after stroke.

The role of occupational therapists is to provide repetitive training using a feasible upper limb function task menu.

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■ORIGINAL ARTICLE

Prefrontal Cortex Activation during Writing and Hand-Shape Changing Dual-Task Performance: A Near-Infrared Spectroscopy Study

Noriko Yamaguchi[1], Sayaka Okahashi[2], Priscila Yukari Sewo Sampaio[3], Toshiko Futaki[2]

[1] Division of Occupational Therapy, Department of Rehabilitation Medicine, Kobe Rehabilitation Hospital, Kobe, Japan
[2] Division of Occupational Therapy, Department of Human Health Sciences, Graduate School of Medicine, Kyoto University, Kyoto, Japan
[3] School of Physical Education, University of Campinas, Campinas, Brazil

Abstract: Aim: To clarify the characteristics of desktop dual tasks that cause dorsolateral prefrontal cortex (DLPFC) activation. **Methods:** Subjects (29 young adults and 22 middle-aged adults) performed three different combinations of dual tasks composed of a pencil and paper task (copying numbers or calculation) and a hand-shape changing task (in response to visual hints or self judgment). We measured brain activation using near-infrared spectroscopy. **Results:** Right DLPFC activation was significantly higher for the simplest dual task than the complex dual task with the younger group, whereas there was no significant difference between tasks with the middle-aged group. Task performance was higher in the younger group than the middle-aged group, whereas there was no difference in brain activation between the two age groups. **Conclusion:** A dual task including two of each task performed automatically could be used for training frontal lobe functions, and the difficulty level should be adjusted depending on age.

Keywords: dual task, near-infrared spectroscopy, prefrontal cortex

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Introduction

In Japan, which is becoming a super-aged society, care for patients with dementia is one of the main issues for mental health and rehabilitation services. A significant symptom of dementia, the behavioral and psychological symptoms associated with dementia (BPSD), prevents patients from doing many activities of daily living (ADL) by themselves in their home and community life. Therefore, it is important not only to inhibit the disease progression but also to prevent and care for BPSD. One of the countermeasures for these illnesses is cognitive rehabilitation, which is a non-pharmacotherapy approach and is well-recognized to prevent or delay dementia.

So far, several studies have reported the effectiveness of cognitive training in improving patients' quality of life [1−5]. Cognitive rehabilitation programs for activating the prefrontal cortex (PFC) help to prevent dementia and mild cognitive impairment (MCI) [3]. However, there is not enough evidence for clinical applications.

Nowadays, there are various functional neuroimaging methods to measure human brain activation, for example magnetic resonance imaging, single photon emission computed tomography, positron emission tomography, and so on. Near-infrared spectroscopy (NIRS) has benefits for subjects because it is not invasive or restrictive of body movement, so that the flexibility of the method is high [6], and we have used this technique to investigate the difference on task performance, brain activation and subjective assessment in relation to the difficulty levels of a virtual shopping test [7]. In the present study, we tried to clarify what kind of task activates the PFC highly by comparing hemodynamic data during different types of dual-task performance using NIRS.

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Corresponding to: Toshiko Futaki, Human Health Sciences, Graduate School of Medicine, Kyoto University, 53 Kawahara-cho, Syogoin, Sakyo-ku, Kyoto 606-8507, Japan
e-mail: futaki.toshiko.2c@kyoto-u.ac.jp
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It was reported that elderly people maintain the ability to perform ADLs such as eating and getting dressed for a long time by increasing their neural network, regardless of neurodegeneration caused by aging or disease [8]. There are many possibilities that cognitive training using a dual task that needs working memory and alternating attention in relation to PFC activation could lead to an increase in neural networks and help to maintain independent personal/social life. Working memory plays an important part in the functioning of alternating attention [9]. A neuropsychological model of attention: the supervisory attention system (SAS) was proposed as a central executive of working memory in PFC [10, 11]. The dorsolateral prefrontal cortex (DLPFC) plays a major role in modulating working memory [12].

Additionally, it was reported that dual-task performance required working memory in relation to the DLPFC, in particular, the left DLPFC was activated during mental calculation performance [13]. It has also been reported that performing a dual task (e.g. doing arithmetic and a physical activity task at the same time) was effective for maintaining cognitive functions in elderly people [14]. Therefore, we adopted a type of asthmatic task as part of our dual tasks to investigate DLPFC activation.

We designed dual tasks that could be used conveniently at home or in occupational therapy sessions in various facilities. We combined two simple and familiar desktop tasks together as a dual task: a writing task based on the hundred square calculation task, and a hand-shape changing task based on the "rock-paper-scissors" game [15]. The hundred square calculation involves simple addition, and is widely used with elementary school students to improve their basic learning skills including attention and memory. "Rock-paper-scissors" is a popular children's game using the hand in Japan. We considered that Japanese people could perform the hand gestures in this game automatically regardless of their age, using both procedural memory and declarative memory.

This study aimed to clarify the characteristics of the desktop dual task in relation to working memory and alternating attention, which causes DLPFC activation, and to verify the difference between healthy younger adult subjects and middle-aged adult subjects in dual-task performance and DLPFC activation.

Methods

1. Subjects

Subjects' characteristics are described in Table 1. A total of 51 subjects participated in this study. They were divided into two groups: a younger adult group (n = 29, age range: 20−35) and a middle-aged adult group (n = 22, age range: 48−60). Frontal assessment battery (FAB) and trail making test (TMT) were conducted as neuropsychological assessments. There were significant differences in age, years of education, MMSE, FAB, and TMT between the two groups.

Table 1. Subjects characteristics.

	Young group (n = 29) Mean (SD)	Middle-aged group (n = 22) Mean (SD)	
Male : female	11 : 18	9 : 13	
Age	23.4 (2.98)	53.2 (3.59)	*
Education years	16.1 (1.94)	15.1 (1.96)	*
MMSE (/30)	29.6 (0.77)	28.9 (1.02)	ns
FAB (/18)	17.1 (0.83)	16.2 (1.65)	*
TMT (s)	6.9 (12.33)	17.3 (19.16)	*
TMT-A (s)	60.0 (17.22)	72.7 (17.37)	*
TMT-B (s)	66.9 (16.59)	90.0 (18.08)	*

* significant different between young group and middle-aged group by t-test ($p < 0.05$).
MMSE: Mini-Mental State Examination. FAB: Frontal Assessment Battery. TMT: Trail Making Test.
TMT = time required to complete TMT-B−time to required complete TMT-A

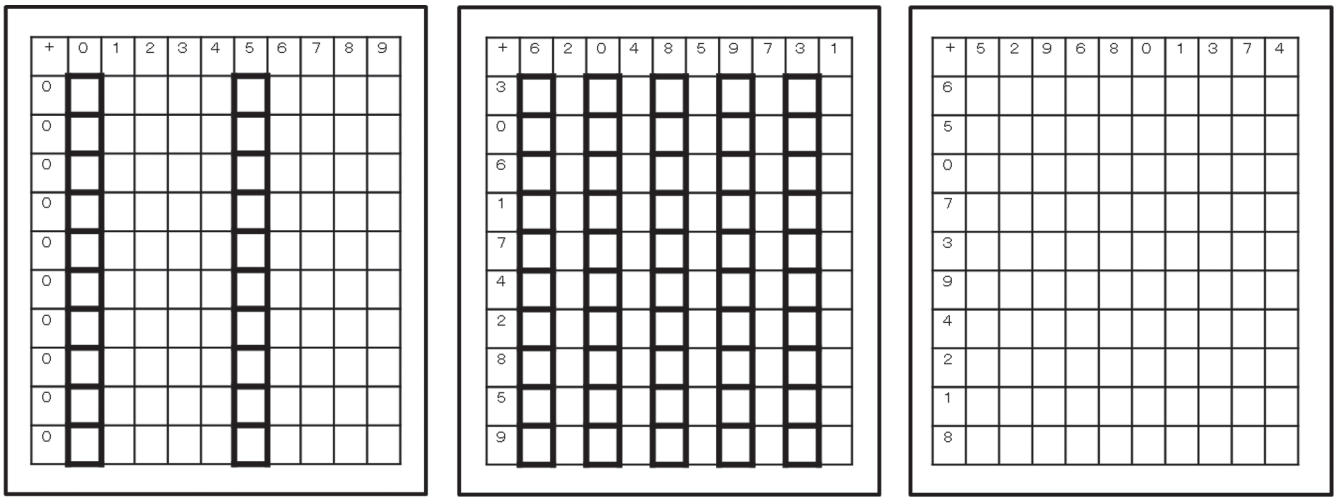
The selection criteria were persons who lived independently in the community without mental and/or neuropsychological diseases such as cerebrovascular disease; and those who were right hand dominant as evaluated using the Edinburgh inventory (laterality quotient > 0) [16]. The exclusion criteria were 1) individuals who had visual impairment; 2) individuals with motor deficits that affected dual-task performance; 3) Mini-Mental State Examination (MMSE) score of ≤ 26 points.

All cognitive functions decrease consistently with aging. In particular, processing speed starts decreasing rapidly around the age of 50 years [17]. For this reason, we set subjects in the middle-aged group as people aged over 45 years old. The study protocol was approved by the Kyoto University Graduate School of Medicine Ethics Committee (E-1114, 2011).

2. Three dual tasks using both hands

We utilized three original dual tasks (e.g. Tasks A, B, and C) consisting of a "hundred square calculation task" performed with the right hand and a "*hand-shape changing task*" with the left hand placed on a table.

Fig. 1 shows the task sheets used in Tasks A, B, and C (in Fig. 1a, 1b, and 1c, respectively). Subjects were asked to fill in the blank squares with numbers by referring to the top and left edges of the table while using their right hand. They completed each row of the table



(a) Task A (b) Task B (c) Task C

Fig. 1. A4 sized task sheets used in threetasks.

starting from left to right and then working from top to bottom. Subjects were asked to add the two numbers shown at the top and the left side of the table, then write the answer in the intersection square between them.

In addition, subjects were also asked to switch the shape of their left hand whenever they filled in a square with a thick border in Tasks A and B. Conversely, in Tack C they were asked to switch the shape of their hand whenever they wrote an odd number after writing an even number (or an even number after writing an odd number) in the previous square. Subjects started with a "rock" pattern, in which the fist was clenched, then change to the "scissors" shape by extending only two fingers (index and middle fingers like scissor blades) and finally "paper" by extending all five fingers out flat.

Subjects were instructed to perform the dual tasks as accurately and quickly as possible. The evaluation items were the number of answers written in 60 seconds, and the number of completed switches of the left hand shape.

3. Procedure

The experimental protocol is shown in Fig. 2. In advance, we provided the instructions and a small practice task for subjects to understand how to execute the dual tasks, then NIRS data during the tasks were measured for a total of six 60-second sessions (3 tasks × 2 trials) continuously. We set a rest period between sessions to allow brain activation level to subside after the previous task. Subjects were instructed to sit in a comfortable and relaxed position, placing both hands on the armrests for the rest periods while looking at the white paper in front of them.

4. NIRS data collection

As shown in Fig. 3, subjects sat in a chair with their feet on the ground during task performance, and they were asked not to talk or move their body or head except for the hand movements required in task execution. Subjects filled in a sheet for the hundred square calculation on a document stand by using their right hand, and they kept their left hand placed on the left side of the document stand on the desk.

We used a multichannel NIRS instrument, FOIRE-3000 (SHIMADZU Co. LTD, Kyoto, Japan) to measure brain activation status from the point of view of hemodynamic changes during dual-task performance. As shown in Fig. 4, we set 27-channel NIRS probes on

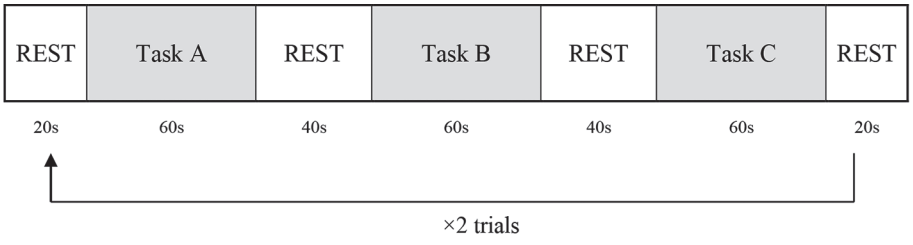


Fig. 2. Experimental protocol.

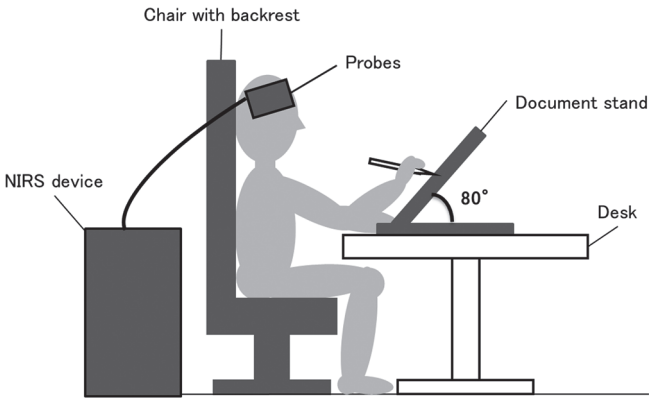


Fig. 3. Experimental setup.

the forehead of the subject corresponding to the international 10−20 system, and the lowest probes were placed along Fp1-Fp2. We set a total of 18 probes including emitters and detectors, in which the distance between each probe was 3 cm.

The NIRS system calculated relative changes in the concentrations of oxygenated hemoglobin ([OxyHb]), deoxygenated hemoglobin ([DeoxyHb]), and total hemoglobin. We used the changes in [OxyHb] values to investigate changes in regional cerebral blood volume in this study, based on the report that [OxyHb] is more sensitive than [DeoxyHb] as a parameter to measure blood flow changes associated with brain activation [18]. We reset hemodynamic data at the start of each task and recorded the change in [OxyHb] for 60 seconds during the performance of each task.

The system used a sampling time of 260 milliseconds. The intensity of the light detected at three wavelengths (780, 805, and 830 nm) was measured, and changes in the optical density were calculated.

5. Data analysis

We selected one of five specified channels in each DLPFC area (e.g. channels 6/12/17/18/23 for right DLPFC, channels 11/16/21/22/27 for left DLPFC) on the basis of the waveforms. We determined these channels as the DLPFC region, which was nearly the same as the Brodmann area 46 involving executive functions, by referring to a previous study [19]. The positions of two channels adopted were symmetrical and fixed on all tasks individually. A dual-task type (Task A, B, or C) × Group (younger, middle aged) analysis of variance (ANOVA) was conducted to evaluate behavioral data and changes in [OxyHb] in DLPFC using SPSS Version 19. Differences were reported as significant when $p < 0.05$.

Results

1. Comparison of task performance between younger and middle-aged adult groups

Regarding the hundred square calculation task, the mean (SD) accuracy scores were 100% (0) in Task A, 99.02% (1.31) in Task B, and 99.41% (0.93) in Task C in the younger group, while they were 99.97% (0.12) in Task A, 97.25% (3.54) in Task B, and 99.00% (1.57) in Task C in the middle-aged group.

Fig. 5a shows the comparison of writing task performance between the two age groups. The task performance score indicated the total number of written answers, including correct and incorrect ones. The result of ANOVA (3 tasks × 2 age groups) showed a significant main effect of the task ($p < 0.0001$) with no interaction. There was also a significant main effect of age group ($p < 0.0001$). The scores were higher in Task A than in Tasks B and C ($p < 0.001$); scores were also higher in

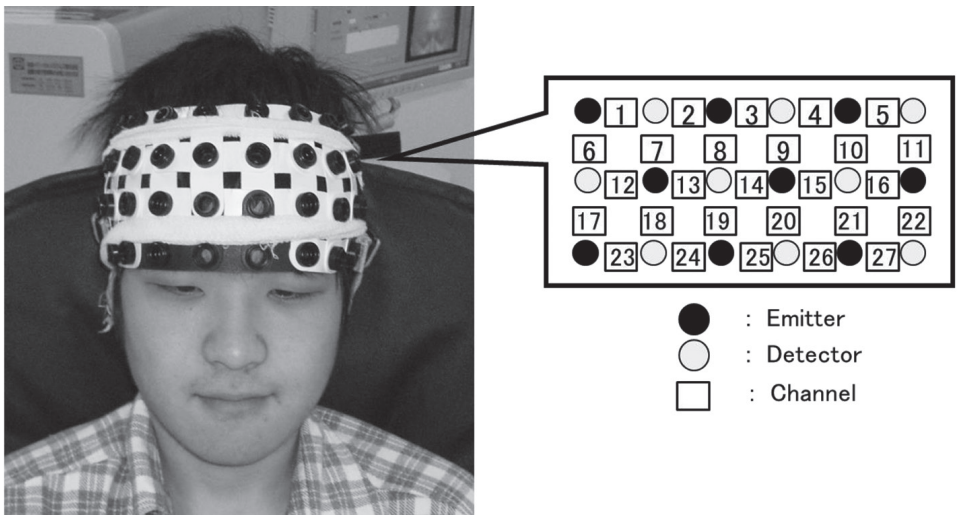


Fig. 4. NIRS channel arrangement on the forehead.

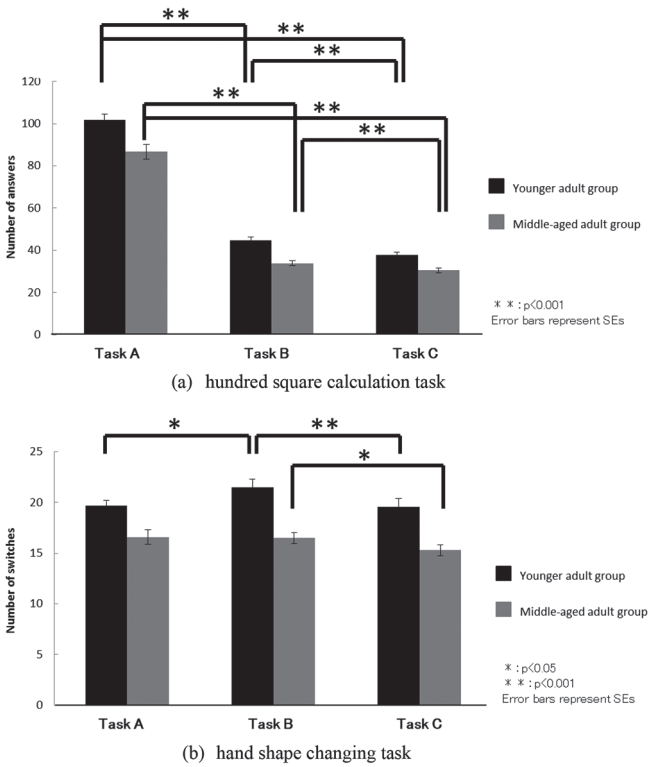


Fig. 5. Comparison of the task performance between tasks in age groups.

Task B than in Task C ($p < 0.001$) in both groups.

Fig. 5b shows a comparison of hand-shape changing performance between the two age groups. The task performance score indicated the total number of left hand movements including correct and incorrect ones. The result of ANOVA (3 tasks × 2 age groups) showed a significant main effect of the task ($p = 0.005$) with no interaction.

There was also a significant main effect of the age group ($p < 0.0001$). The score was higher in Task B than in Task A ($p = 0.007$) and Task C ($p < 0.001$) in the younger adult group, whereas it was higher in Task B than in Task C ($p = 0.016$) in the middle-aged adult group.

2. Comparison of DLPFC activation between younger and middle-aged adult subjects

Fig. 6 shows sample NIRS data on changes in [OxyHb] during Task A. Right DLPFC (e.g. channel 17) and left DLPFC (e.g. channel 22) activation was observed during task performance.

Fig. 7 shows a comparison of DLPFC activation between tasks in the two age groups. Fig. 7a shows the right DLPFC, and Fig. 7b shows the left DLPFC. The result of ANOVA (3 tasks × 2 age groups) on [OxyHb] change showed a significant main effect of the task in the right and left DLPFC ($p = 0.003$ and $p = 0.019$, respectively) with no interaction. There was no significant main effect of age group in any area of DLPFC. The right and left DLPFC were activated more highly during the performance of Task A than during Task C ($p = 0.002$ and $p = 0.007$, respectively, after Bonferroni correction).

Analysis using the Holm method showed the following. The right DLPFC was activated more highly during the performance of Task A than during Task C in the younger adult group ($p = 0.007$). There was no significant difference between Task A and Task C in the middle-aged adult group ($p = 0.030$) in the right DLPFC. On the other hand, there were no significant

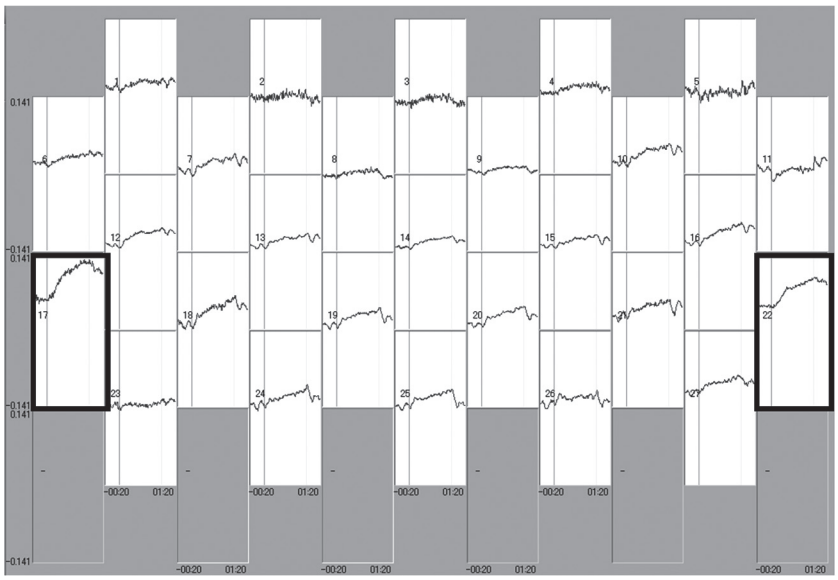


Fig. 6. A sample NIRS data on change of [OxyHb] during Task A performance.

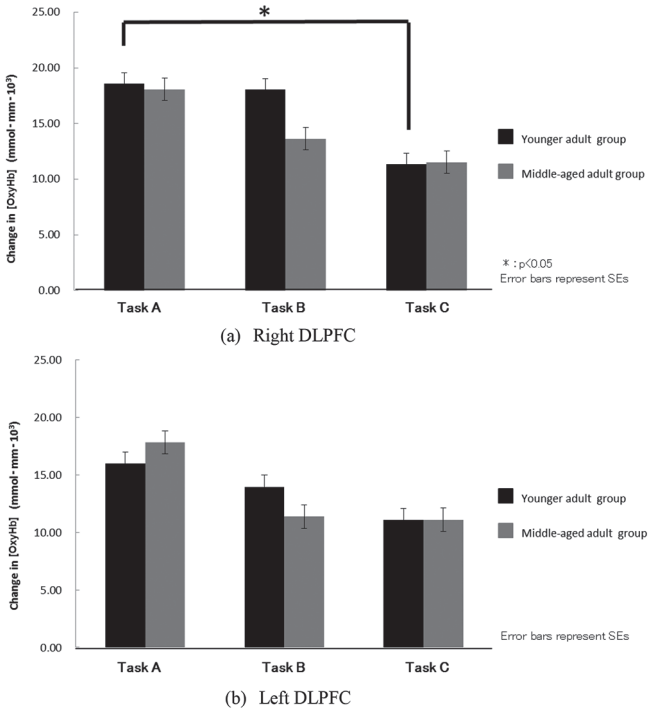


Fig. 7. Comparison of the DLPFC activation between tasks in age groups.

differences between Task A and Task C in either group ($p = 0.037$ and $p = 0.034$, respectively) in the left DLPFC.

Discussion

This study aimed to clarify the characteristics of a desktop dual task to determine which caused DLPFC activation more easily, and to verify the difference between younger and middle-aged adults during dual-task performance and with regard to DLPFC activation. Participants performed three dual tasks composed of a pencil and paper task using their right hand (copying numbers in Task A; calculation in Tasks B and C) and a hand-shape changing task using their left hand (on cue from visual hints in Tasks A and B, and by self judgement in Task C).

Regarding the characteristics of DLPFC activation, it found that the right DLPFC activation was significantly higher with the simplest task (Task A) compared with the complex task (Task C) in the younger adult group, whereas there was no significant difference between tasks in middle-aged adult group. We considered that Task A was a dual task composed of the easiest tasks of the three, which should not interfere with each other directly, and it was possible for the subjects to perform this task without much difficulty. On the other hand, Task C was a dual task combined of two tasks requiring both calculation and self-judgment, which could interfere with each other. On the basis of data from younger subjects, it was suggested that the simple dual task composed tasks performed using both hands automatically had a tendency to activate the DLPFC highly.

As a reason for the fact that there was no significant difference in DLPFC activation between tasks for the middle-aged group, we considered that all dual tasks used in this study, even Task A, imposed too high a load for middle-aged subjects to activate their brain. So far, it has been reported that the compensation-related utilization of neural circuits hypothesis (CRUNCH) has a relationship with age-related brain activation [20]. According to this hypothesis, more neural resources are engaged by older brains to accomplish computational goals completed with fewer resources by younger brains. Therefore, older adults were more likely than younger adults to show over-activation at low load, and under-activation at high load.

The task performance results varied depending on age: younger adult subjects performed better on each dual task than the middle-aged subjects. In contrast, there was no significant difference in brain activation during each task execution, although the activation patterns in [OxyHb] change were similar between the groups. As shown in Table 1, there were differences in cognitive test scores (e.g. TMT representing attention and FAB representing frontal lobe function) between the two age groups. There is a possibility that the differences in basic cognitive functions were related to the difference in the tendency on task performance between the two groups.

In addition, the characteristics of attention required in the execution of a specific task influenced the task difficulty [21]. We considered that all of the three dual tasks would need attention capacity but have their own characteristics. With respect to the hand-shape changing task performance, subjects could execute the motion switching itself automatically in all dual tasks. However, Tasks A and B required the processing of visual information as a trigger for the hand-shape change by using divided attention and procedural memory mainly. Task C required higher functioning such as SAS [10, 11] involved in working memory, as described in Introduction section, by judging the number in each answer in comparison with the previous one. We considered that these various aspects of cognitive functions required in each dual task could influence task performance and brain activation.

A previous study reported that young and old participants showed significantly greater PFC activation during dual-task performance than single-task performance by using stepping and mental arithmetic called “serial 7”, which are simple tasks using automatic

processing [22]. Although the type of dual task used here was different from the previous study, we found that the dual task using both hands but composed of two tasks that subjects performed automatically activated the DLPFC similarly.

Our study had some limitations. The brain activation data varied even in a single age group owing to individual differences. We plan to collect a larger data set to resolve the relationship between task performance and brain activation as a subsequent study. After revisions to make our dual tasks easier, a further study investigating brain functions according to task characteristics is needed to improve cognitive rehabilitation for elderly people and patients with dementia or MCI.

Conclusion

This study examined the impact of the characteristics of dual tasks on prefrontal lobe activation in younger and middle-aged adult subjects. As a result, a simple dual task composed of two tasks each performed automatically caused higher DLPFC activation than a more complex dual task requiring judgment in younger subjects. The task performance was higher in the younger adult group than in the middle-aged adult group. It was suggested that a desktop dual task including the performance of two easy tasks using both hands simultaneously could provide a cognitive training task to promote DLPFC activation, and the task level should be adjusted for each person's ability considering age.

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■CASE REPORT

Driving risk in a stroke patient with mild cognitive deficit could not be predicted by neuropsychological testing: a case report

Tatsunori Sawada[1], Yoshio Fujita[2], Mika Shiratori[1], Masanao Shibuya[1]

[1] Department of Rehabilitation, IMS Itabashi Rehabilitation Hospital
[2] Division of Occupational Therapy, Faculty of Health Science, Mejiro University

Abstract: Neuropsychological, off-road, and on-road testing were used to assess the driving skill of a stroke patient to determine whether he could drive safely. Driving risk could not be detected by neuropsychological testing, but was detected with the Useful Field of View (UFOV) test and a driving simulator and confirmed with on-road testing. Although it may be more effective to use on-road testing or a driving simulator to assess whether a stroke patient is competent to drive, our results suggest that UFOV may be more a more accessible and cost-effective method for detecting driving risk due to mild cognitive dysfunction.

Keywords: driving skill, cognitive dysfunction, useful field of view (UFOV)

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Introduction

Rehabilitation of stroke survivors often requires medical staff to decide whether the patient is competent to drive. This decision must be made carefully to avoid the possibility of driving accidents caused by stroke-related impairments. Cognitive dysfunctions are often more serious factors than motor deficits for stroke patients who wish to drive because driving an automobile requires a high level of cognitive skills [1−4]. On-road driving is the gold standard for assessing fitness to drive for people with disabilities [5]. However, on-road driving assessment may be expensive and require much time for patients [3]. Furthermore, traffic laws in some countries restrict stroke patients from driving on public roads for evaluation of their skills. In cases where on-road testing is not feasible, neuropsychological testing, the Useful Field of View (UFOV) test, and driving simulators are frequently used alternatives. Because the cost of the driving simulators prevents many hospitals from using this device, neuropsychological testing is most frequently used for driving assessment.

Many researchers have reported a relationship between neuropsychological testing and driving skill, and meta-analyses and systematic reviews have revealed such a correlation [3, 6]. Understandably, clinicians desire valid and reliable tools to accurately and easily assess the driving risk associated with cognitive dysfunction [2, 7].

In this article, we report that driving risk in a stroke patient could not be detected with neuropsychological testing and that the use of a driving simulator and the UFOV test revealed visuospatial and attention deficits. The driving risk of this patient was confirmed with on-road driving assessment. As required by the Ethics Committee of our hospital, written consent was obtained from this patient for publication of this article.

Case introduction

A 52-year-old man experienced sudden onset of loss of consciousness and developed a cerebral infarction after atrial fibrillation. He was diagnosed with cardiogenic cerebral infarction of the right middle cerebral artery region, with damage from the putamen to corona radiata confirmed by magnetic resonance imaging.

He received conservative treatment in an acute hos-

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Corresponding to: Tatsunori Sawada, Department of Rehabilitation, IMS Itabashi Rehabilitation Hospital, 3-11-1 Azusawa, Itabashi, Tokyo 174-0051, Japan
e-mail: sawada.tatsunori@ims.gr.jp
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pital and was discharged from a rehabilitation hospital 3 months after onset. Simple Test for Evaluating Hand Function scores (right upper extremity 90, left upper extremity 83) revealed no motor or sensory deficits. The patient's functional independent measure score was 125 when he was discharged from the rehabilitation hospital. He experienced no problems or complications during hospitalization. He received a medical driving-skill evaluation at our hospital as an outpatient.

Protocol for driving skill evaluation at our hospital

The driving assessment protocol used at our hospital is summarized in Fig. 1. Initially, we interview a patient to determine driving history, car model, and the patients' plans to drive in the future. In addition, the patient attends a lecture of approximately 1 h regarding traffic law and legal procedures before returning to driving, which raises awareness of issues facing drivers after brain injury. Subsequently, the patient is evaluated with off-road testing, including neuropsychological testing, visual acuity testing, and performance in a driving simulator. The patient's abilities to adjust the seatbelt and side mirror and to operate the steering wheel and brake and acceleration pedals are evaluated in a parked car. The on-road driving assessment (Fig. 1) is used only in cases of considerable doubt, as the ability of the medical staff to evaluate a patient's driving skills with on-road testing in Japan is limited institutionally and financially. We refer to previously reported cut-off points (Table 1) for each neuropsychological testing [2, 8]. In addition, competency to drive is not determined with only a single abnormal result, but instead is comprehensively assessed using many results from multiple tests.

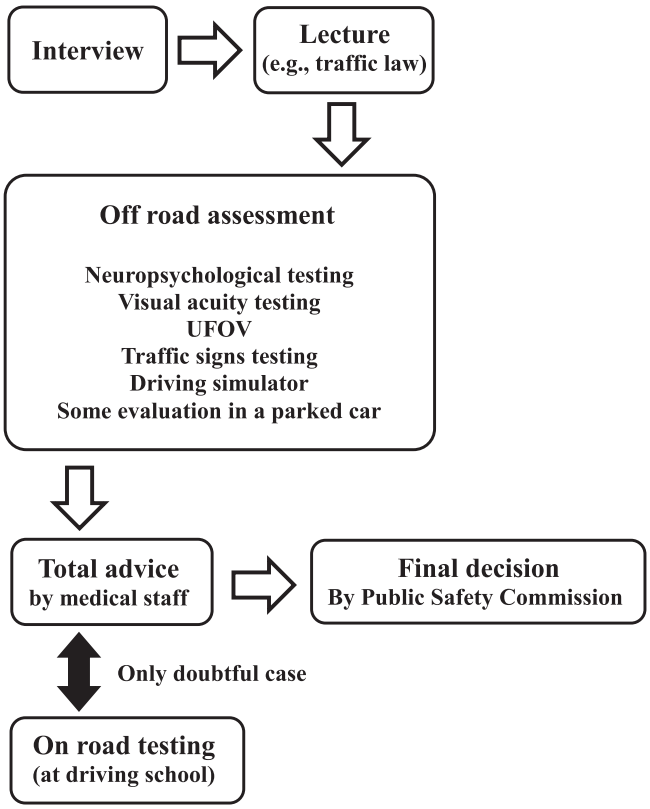

Fig. 1. Protocol for driving assessment used at our hospital. The patient attends the lecture and is assessed using many evaluations.

Interview

The patient demonstrated strong motivation to drive, as he had a son still in high school and a wife to support. He hoped to be able to drive a car again to maintain his employment at an apartment management company, which required him to transport staff by car. His job required him to drive 5−6 h per working day. He

Table 1. Cut-off scores for testing.
We referred to previously reported cut-off point based systematic review for neuropsychological testing.

Type of testing	acceptable	doubtful	unacceptable
Mini-Mental State Examination	28 or more	27-23	22 or less
Rivermead Behavioral Memory Test			
screening	7 or more	−	5 or less
standard profile	16 or more	−	14 or less
Rey-Osterrieth Complex Figure Test (copy)	34 or more	30−34	29 or less
"A" Random letter Test	0		1 or more
Trail Making Test-A	42 sec or less	43−54 sec	55 sec or more
Trail Making Test-B	148 sec or less	149−180 sec	181 sec or more
Behavioural Inattention Test			
conventional test of score	131 or more	−	130 or less
behavioral test	68 or more	−	67 or less
Kohs block design test	IQ 90 or more	IQ81−89	IQ 80 or more
Japanese road signs (original assessment in our hospital)	10 or more	8−7	6 or less

was eager to return to his work as soon as possible, as he feared being fired due to the current difficult economic condition. He had committed some mild traffic violations. Although he had never caused a traffic accident resulting in injury, he had caused an accident resulting in property damage. According to his wife, he exhibited no particular changes in comparison to his behavior, personality, and abilities prior to the stroke.

Off-road testing results

The patient had no hemianopia. The following are the results of several off-road tests completed by the patient: Mini Mental State Examination score was 28; Rivermead Behavioral Memory Test screening score was 12 and standard profile score was 18; Rey-Osterrieth Complex Figure Test (only copy) score was 35; "A" Random letter test error value was 0; Trail Making Test (TMT) A was completed in 46 s; TMT-B was completed in 48 s; Behavioral Inattention Test (BIT) conventional test score was 146 and behavioral test score was 77; and Kohs Block Design Test IQ was 85.4. In addition, the patient correctly identified 19 out of 20 Japanese road signs in an original assessment used by our hospital, and his vision in both eyes was 0.8 while wearing his glasses. Although these results were not perfect, our medical team could not confirm driving risk.

When tested in a parked car, the patient did not exhibit any notable problems while opening and closing the car door, adjusting the seatbelt and mirrors, inserting the key, or adjusting the speed when operating the steering wheel or stepping on the brake or acceleration pedal. In this test as well, our medical team could not confirm driving risk.

UFOV testing result

The Visual Field with Inhibitory Tasks (VFIT) software was used to assess the UFOV or functional visual field (FVF) using dual tasks (Fig. 2) [9]. During the assessment, the useful field of view is measured as the seated patient watches a computer monitor placed on the desk in front of him or her. The VFIT comprises three pretests (simple task, go/no go task, and peripheral task) and a dual task of combined pretests. We adopt tasks excluding the peripheral task. At first, subjects must gaze at the center of the monitor during all tasks.

Four target marks (4 types) on the monitor are indicated for 2500 msec–3000 msec, and subjects must push a button immediately according to various tasks. The simple task is that the subject must always push the button when the target marks appeared on the monitor. If the subject pushes the button before the target marks

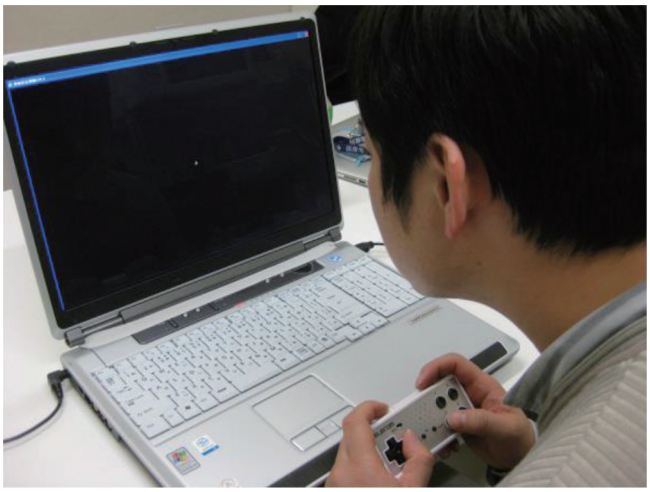

Fig. 2. Visual Field with Inhibitory Tasks (VFIT) setup. VFIT software is used to assess the UFOV. Subject sits on the front of PC monitor. They need to push the button for correct reaction.

appear, the result will be a "false alarm (FA)" (same as other tasks). If the subject cannot push the button correctly, the result is an error. The go/no go task requires the subject to push the button only when all target marks are different from each other. If the subject pushes the button when some target marks are the same, the result will be FA (same as dual task). In the dual task, a single target mark (a surrounding mark) appears around four target marks, and the subject must push the button only when all target marks in the center of the monitor are different. After that, the subject must push a predetermined button corresponding to the surrounding mark types. There are four versions (I, II, III, and IV) of the dual task depending on the distance between the target marks and the surrounding mark.

The percentage of correct answers for each stage (peripheral task; indicates the width of the useful field of view) and the number of FAs are recorded. Although no defined clear cut-off scores have been established for VFIT, VFIT developers indicated that the average score for people of the same age as the patient was approximately 90%, and the cut-off score was estimated to be approximately 80% [9].

The patient's performance on the VFIT was as follows: the percentage of correct answers was 100% in the simple task, 100% in the go/no-go task, and, in the dual task, 84% in stage I, 93% in stage II, 84% in stage III, and 75% in stage IV. The number of FAs was 6% in the go/no-go task, and, in the dual task, 9% in stage I, 6% in stage II, 6% in stage III, and 0% in stage IV. He made mistakes on both left and right sides (slightly more often on the left side) during VFIT (Fig 3).

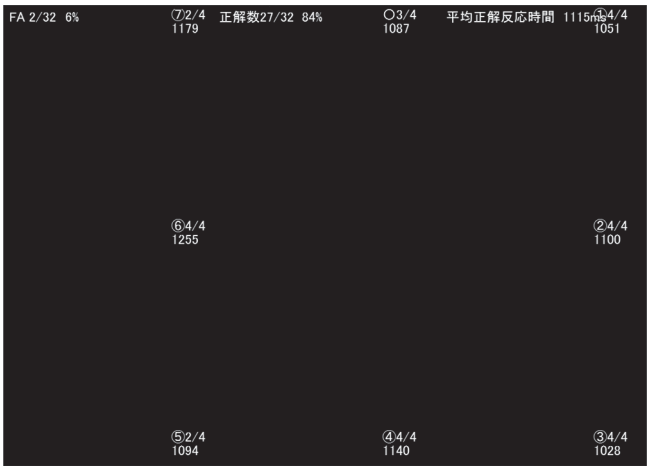

Fig. 3. Result screen from the VFIT (dual task Stage III). This screen indicates the dual task Stage III of the VFIT. Our patient made mistakes on both left and right sides (only left or middle side in this figure).

Driving simulator

We adapted the UC-win/ROAD software version 3.4 (FORUM8 Co., Ltd) as a driving simulator (Fig. 4). The software provides a steering function that is similar to a TV driving game and is not similar enough to a car to assess steering. Therefore, other driving skills, such as the ability to stay in the center of the lane and to remain stationed at a red traffic signal, are assessed using this simulator.

During assessment with this driving simulator, the patient could not keep to the center of the lane, tending to drive on the left side of the road, and crossed over a guard rail and a side walk. Several times an occupational therapist directed him to drive in the center of the lane, after which he initially drove in the center but eventually tended to drive on the left side. No other problems were observed.

Fig. 4. Driving simulator. UC-win/ROAD software version 3.4 (FORUM8 Co., Ltd). This simulator can reflect the virtual road on three computer screens. But this software is not similar enough to a car to assess steering.

On-road testing

The results of the driving simulation and VFIT raised doubts on the patient's competency to drive and an on-road assessment was deemed necessary. We adopted ordinary driving skill evaluation items (e.g., the outer circumference of the course road, slope, and crank) for which healthy driving students are tested. In the 1-h on-road assessment, a driving instructor sat in the front passenger seat, and an occupational therapist sat in the back seat. The patient exhibited no difficulties when instructed to start the car on a hill, stop on a line, and turn a corner. However, when he carefully attempted to stop the car on the left side of road, he scratched the left tire on the curb. Although the occupational therapist and instructor warned him repeatedly, he scratched the left tire in six out of nine attempts to park on the left side of the road.

From the results of this series of driving assessments, we concluded that the patient was not yet ready to drive due to suspected attention deficits. As the patient showed improvement since the stroke and the impairment was mild, the clinician informed the patient and his wife that there was a possibility that he might be competent to drive in the future. In addition, the physician provided the patient with a medical certificate stating that, with the exception of driving, he was able to return to work. The patient returned to work as a clerical staff without driving responsibilities, and he completed regular ambulatory care at our hospital.

Discussion

In this study, the assessment of a stroke outpatient using neuropsychological tests and off-road assessment in accordance with our protocol did not reveal driving risk. Because visuospatial Meyers, Volbrecht, & Kaster-Bundgaard [10] and attentional Parasuraman & Nestor [11] functions are critical to driving skill, BIT and TMT were performed and did not reveal driving risk. However, on-road assessment revealed that the patient experienced difficulty in stopping the car on the left side of the street, and it was concluded that the risk of driving was sufficiently high to indicate he was not ready to drive yet. The patient's driving risk could not be detected by neuropsychological testing, and this was

likely due to the presence of very mild cognitive disorder. A previous study showed that it was easy to detect driving risk for patients with moderate or heavy cognitive disorders, but that it was more difficult to assess the driving risk for patients with mild cognitive disorders [3]. In a study that found a correlation between visuospatial or attention and driving skill, cognitive dysfunction could not be detected with neuropsychological testing [10, 11]. Another study indicated that there is no correlation between neuropsychological testing and driving skill [12], and our results support this conclusion. Although it is possible that our study is a rare case in which driving risk could not be assessed with neuropsychological testing, it should not be dismissed as the risk of accident was considerable.

VFIT and driving simulator assessment also revealed the driving risk of the patient. Previous studies indicated that the UFOV test can be used to assess various cognitive functions (e.g., attentional, visuospatial), that it was superior for detecting the driving risk of elderly drivers, and that the results correlate well with on-road assessment as well as TMT and Rey-Osterrieth Complex Figure Test results [2, 13]. The fact that we could detect a mild cognitive disorder using VFIT and driving simulator suggests that these assessments may be useful for assessing driving risk that cannot be detected with neuropsychological testing. Although driving simulators may be prohibitively expensive, cognitive disorders contributing to driving risk can be assessed in a hospital using only VFIT and a personal computer, because the developer of VFIT offers the test for free with some requirements.

Ultimately, on-road testing is still the most useful assessment of driving risk in cognitive disorder patients after brain injury. However, many therapists cannot use on-road testing due to economic and institutional restrictions. Marshall et al. [2], in describing institutional differences in countries with respect to on-road testing, noted that on-road assessment is used primarily in Canada because most physicians must declare the driving competency of patients and, correspondingly, not used as often in the USA because American physicians are not required to report driving competency, usually. At present, only a few hospitals in Japan use on-road testing. Although Japanese physicians do not have the authority to decide whether a patient can drive or not, driving license authorities often seek medical advice for granting driving privileges, because on-road testing is rarely performed by this organization. Physicians required to assess the driving competency of patients are faced with the disadvantages of neuropsychological testing and a lack of cooperation from driving schools. To address these issues in Japan, we suggest that driving license authorities should employ individuals, such as occupational therapists, who have the knowledge of neuropsychology and driving skill assessment. Until such policy is implemented, driving risk can be assessed in hospitals using the UFOV test or driving simulators.

Conclusion

We used neuropsychological, off-road, and on-road testing to determine the driving skill of a stroke patient. Although driving risk could not be determined by neuropsychological testing, it could be determined by the UFOV test and a driving simulator. Although it may be most effective to use a combination of neuropsychological, off-road, and on-road testing to determine the driving competency, our results suggest that the UFOV test may be a useful alternative when on-road testing and driving simulation is unavailable.

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■ORIGINAL ARTICLE

Reasons for the Lack of Practice using Public Transportation at Sub-acute Rehabilitation Hospitals in a Japanese Urban Community

Masahiro Ogawa[1], Tatsunori Sawada[2], Chinami Ishizuki[3], Sayaka Okahashi[1], Toshiko Futaki[1]

[1] Department of Human Health Sciences, Graduate School of Medicine, Kyoto University, Kyoto, Japan
[2] Department of Rehabilitation, IMS Itabashi Rehabilitation Hospital, Tokyo, Japan
[3] Health Sciences Major, Graduate School of Biomedical & Health Sciences, Hiroshima University, Hiroshima, Japan

Abstract: Using public transportation is crucial for people living in urban communities. However, a previous study suggested that approximately one-third of sub-acute rehabilitation hospitals in Japan could not practice using public transportation. Here we aimed to quantitatively and qualitatively examine why these hospitals did not practice. Managerial occupational therapists working in sub-acute rehabilitation hospitals in urban Japan were enrolled. Using a postal survey, some questions regarding the practice of using public transportation were asked. Two hundred and twenty-eight responses were analyzed. The frequency of practicing the use of public transportation was weakly correlated with the hospital bed number, therapist number, and average therapy duration. The qualitative data concerning reasons for not practicing were integrated into four categories: barriers of social system, specific factors of the task, existence of complementary method, and lack of necessity and awareness. It may be important to improve these inhibiting factors for providing appropriate occupational therapy.

Keywords: practice, public transportation, sub-acute rehabilitation hospital

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Using public transportation is important for people living in an urban community to participate in activities outside, e.g., using the railway to commute or taking a bus to shop. A lack of outdoor mobility for the elderly can lead to isolation, poor health, high mortality, and low quality of life [1−4]. Moreover, acquired disability and aging accelerate the disuse of public transportation, which limits their outside participation and narrows their life spaces [5−8]. In an urban community, such as a metropolitan region in Japan, where public transportation has matured, it is a social problem that handicapped and aged people cannot use public transportation.

Occupational therapy can contribute to enhancing the use of public transportation in handicapped and aged persons. Riding public transportation is a physical and cognitive practice, and it also encourages patients and clarifies their problems on using public transportation. A previous post-stroke randomized controlled trial suggested that occupational therapy intervention increased outdoor mobility in the intervention group [9]. Therefore, enhancing outdoor mobility for handicapped and aged people, including the practice of using public transportation, is part of an occupational therapist's remit.

Representative diseases known to cause mobility restriction for the elderly include stroke and hip fracture. For example, Wendel, Stahl, Risberg, Pessah-Rasumussen and Iwarsson [10] reported that one-third of patients after stroke decreased or stopped the use of buses and trains. In Japan, there are unique wards that provide intense rehabilitation for people with such diseases in the sub-acute phase from approximately 2 weeks to 2−6 months after the onset. They are called Kaifukuki Rehabilitation Wards (Kaifukuki means recovery phase in Japanese). More than 80% of patients in these wards had a stroke or fracture and their average age was 75.2 years [11]. Thus, most of the inpatients in the hospitals

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Corresponding to: Masahiro Ogawa, Department of Human Health Sciences, Graduate School of Medicine, Kyoto University, Kyoto, 53 Syogoin Kawahara-cho, Sakyo-ku, Kyoto, 606-8507, Japan
e-mail: ogawa.masahiro.4w@kyoto-u.ac.jp
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are elderly and easily get housebound after handicapped. Moreover, according to our previous research, even if there are many inpatients hoping to use public transportation after discharge and are approved to use it, 29.4% of hospitals cannot practice it [12]. Other studies also indicated that many patients with physical disability who lived at home wished to get out more often [13−14]. Although aging of society has been progressing worldwide, particularly in Japan, studies have revealed undesirable conditions concerning the supply and demand of occupational therapy needs.

Barriers to outdoor mobility for stroke patients have been studied. A previous qualitative study found that the barriers were fear of falling or injury, lack of confidence, and inadequate information about transport services [14]. To reduce these barriers it could be vital to practice riding public transportation as a rehabilitation practice. Why can occupational therapists in some sub-acute rehabilitation wards not practice using public transportation? Investigation of the reasons would give us some meaningful information for adjusting appropriate occupational therapy practices. Moreover, this research could be applied to urban areas of the world to provide knowledge about rehabilitation of public transportation.

The purpose of this study was to quantitatively and qualitatively examine why occupational therapists working in sub-acute rehabilitation wards cannot practice using public transportation in a Japanese urban community. The quantitative method was used to examine correlations between the extent of the practice of using public transportation and the characteristics of sub-acute rehabilitation wards. Furthermore, the qualitative method was used to ask occupational therapists about reasons for not practicing using public transportation.

Methods

Subjects

Using purposive sampling, subjects in the study included managers of occupational therapy departments in hospitals that were selected from a list of sub-acute rehabilitation hospitals in Japan, which were made by the Kaifukuki Rehabilitation Ward Association [15]. The subjects were all associated with hospitals that had sub-acute rehabilitation wards in the regions and cities with a greater than 5% utilization rate of railways during holidays on investigation of the national urban traffic condition [16]. Based on the selection criteria, 453 facilities in the metropolitan region including the Kinki region and Chukyo region as well as Sapporo, Sendai, Hiroshima, and Fukuoka city were selected for the investigation.

A postal questionnaire was sent to the manager of the occupational therapy department in each facility. A document attached to the postal questionnaire provided information about the research purpose, research method, and protection of personal information. The explanation in this document was carefully written to not affect question responses. The questionnaire was filled out anonymously. Returning the questionnaire was regarded as obtaining respondent's consent for participation in the study. The study was approved by the ethics committee at IMS Itabashi Rehabilitation Hospital (approval number: A-006).

Recruitment and data collection

The data collection method was a postal survey with a self-administered questionnaire. The reply deadline was three weeks later. After this deadline had passed, a letter of appreciation including a reminder of their response was sent to all of the subjects and the deadline was extended for two more weeks.

As a precaution, before answering the questionnaire an operational definition of the following terms was explained. In this study, public transportation meant railway and bus and excluded taxies. Practice of using public transportation was defined as practice riding transportation outside the hospital during rehabilitation or an assessment.

Information about the respondents, such as years of clinical experience and managerial position, was gathered. General information regarding the facility included the number of hospital beds, number of therapists (occupational therapists, physical therapists, and speech therapists), average therapy duration for a patient per day, and distance from the hospital to the nearest station and bus stop.

Regarding practice of using public transportation, a question about the frequency was asked. The question was, "How many patients practice using public transportation during rehabilitation, among those who are approved to use it after discharge?" The response was given on a 5-point scale: all of the patients, majority of patients, half of the patients, few patients, and none of the patients. If few patients and none of the patients were answered, an open-ended question was asked regarding the reason for not practicing it. If the practice was not performed, this question was sure to be answered.

Data analysis

Descriptive statistics were calculated for the characteristics of respondents and their facility. Spearman's rank correlation coefficient was used to examine the relationship between the frequency of practice and other variables, including number of hospital beds, number of staff, average therapy duration, and distance between the

hospital and station and bus stop. SPSS 22.0 was used for statistical analysis. The level of significance was set at 0.05.

A qualitative analysis was performed for descriptive data from the open-ended question regarding the reasons for not practicing the use of public transportation using the KJ method [17]. First, the answers that were impossible to understand or misunderstand were examined, for example "can you apply health insurance for payment of rehabilitation outside a hospital such as using public transportation? (counter-question)" These answers were excluded from the analysis. The answers were split into labels so that each label had only one meaning for a question. The labels were gathered by their similarity to make the first-level categories and each of the categories was named so the meaning of the category was represented. Furthermore, following similarity of the categories the second-level categories were made. The same procedure was repeated until the forth-level categories were finally made. To ensure consistency in the analysis, two researchers who had experience with qualitative studies repeatedly confirmed until no further revisions were found. They were occupational therapists and co-authors who had clinical experience more than ten years.

Results

Two hundred and thirty subjects replied. Two of the returned questionnaires had many omissions and were excluded. Therefore, 228 responses were used for the analysis (response rate, 50.3%).

The number and ratio of participants is shown in Table 1. Information regarding the respondents and their facilities is shown in Table 2. Some responses were excluded for each question in the analysis because no answer or an inappropriate answer was given. The average and standard deviation of years of clinical experience was 10.9 years (SD = 5.7) and 81.5% of the respondents held a managerial position. The average number of hospital beds was 70.5 (SD = 54.8). The average number of therapists was 34.8 (SD = 30.2). The average therapy duration for a patient per day was 127.5 min (SD = 32.5; including physical therapy and speech therapy). The average distance from the hospital to the station was 2.0 km (SD = 2.2) and to the bus stop was 0.44 km (SD = 0.51).

Results of the frequency of practice using public transportation are shown in the bottom right of Table 2. Correlation coefficients between the frequency of practice and other variables are provided in Table 3. Correlation coefficients between the frequency of practice are presented with the number of hospital beds (r = .25, p <.001), number of therapists (r = .28, p <.001), and average therapy duration (r = .18, p = .005).

Table 1. Charactristics of respondents.

	n	ratio (%)
Years of clinical experience		
1−5 y	25	11.2
6−10 y	103	46.2
11−15 y	61	27.3
≥ 16 y	34	15.3
No answer	5	
Managerial position		
Vice-principal, general manager, assistant manager	4	2.1
Section manager, chief therapist, senior manager	36	19.1
Section chief, chief clerk	111	58.7
Other managerial position	3	1.6
Staff (non-managerial position)	35	18.5
No answer	39	

Qualitative analysis of reasons for not practicing public transportation use

Eighty-three respondents provided reasons for not practicing public transportation use with the narrative form. From these answers 239 labels were extracted. The average and standard deviation of the number of labels per respondent was 2.8 ± 1.5 labels (range: 1−7 labels). Italics in the following results are quotes of respondents' answers. The numbers in parentheses correspond to the label number.

The data were integrated into 4 categories with the forth-level category as the highest category: 1) barriers of social system (37 labels), 2) specific factors of the task (89 labels), 3) existence of a complementary method (44 labels), and 4) lack of necessity and awareness (69 labels). Based on these categories (Fig. 1), excluding 4) lack of necessity and awareness, the reasons for not practicing public transportation use were 1) barriers of social system and 2) specific factors of the task. These two categories have given rise to 3) existence of complementary method.

1) Barriers of social system

Twenty-nine respondents (34.9%) felt that there were barriers of social system preventing therapists from the practice. This category comprised two lower categories (third-level categories): A) not permitted by hospital administrations (13 labels) and B) imperfections in the social system (24 labels).

A) Not permitted by hospital administrations

Some occupational therapists wanted to practice outside their hospitals, but they had some problems with

Table 2. Facility information and frequency of practice.

	n	ratio (%)		*n*	ratio (%)
Location			Distance from hospital to the nearest station		
Metropolitan region	91	40.5	0.0−0.9 km	65	29.7
Kinki region	72	32.0	1.0−1.9 km	63	28.8
Chukyo region	25	11.1	2.0−2.9 km	43	19.6
Local central cities	37	16.4	3.0 km-	48	21.9
(Sapporo, Sendai, Hiroshima and Fukuoka city)			No answer	9	
No answer	3				
			Distance from hospital to the nearest bus stop		
Number of hospital beds			0.00−0.19 km	91	42.5
1−49 beds	98	44.1	0.20−0.39 km	48	22.4
50−99 beds	78	35.1	0.40−0.59 km	47	22.0
100−149 beds	27	12.2	0.60+ km	28	13.1
150+ beds	19	8.6	No answer	14	
No answer	6				
			The frequency of practice using public transportation		
Number of therapists[a]			All	34	15.2
0−19 therapists	83	37.9	Almost	67	30.0
20−39 therapists	72	32.9	Half	26	11.7
40−59 therapists	24	11.0	Seldom	55	24.7
60−79 therapists	43	18.2	None	41	18.4
No answer	6		Inappropriate answer	1	
			No answer	4	
Average therapy duration for a patient per day					
0.00−0.99 hours	10	5.1			
1.00−1.99 hours	442	2.5			
2.00−2.99 hours	129	65.8			
3.00 hours[b]	13	6.6			
Inappropriate answer	4				
No answer	28				

[a] Number of therapists is the sum of occupational therapists, physical therapists, and speech therapists.
[b] In Japan, up to three hours of rehabilitation per day for an inpatient in sub-acute rehabilitation wards is permitted by the payment system for medical services. This rehabilitation duration includes occupational therapy, physical therapy, and speech therapy.

Table 3. Correlation coefficients between frequency of practice and other variables.

	frequency of practice	
	r	*p*
Number of hospital beds (n = 217)	.25	< .001
Number of therapists* (n = 214)	.28	< .001
Number of occupational therapists (n = 215)	.22	< .001
Number of physical therapists (n = 214)	.21	‘ .001
Number of speech therapists (n = 206)	.21	< .001
Average therapy duration (n = 182)	.18	‘ .005
Distance to the nearest station (n = 212)	.05	‘ .488
Distance to the nearest bus stop (n = 204)	−.05	‘ .468

* Number of therapists is the sum of occupational therapists, physical therapists, and speech therapists.

hospital administers and hospital policy, for example, “*hospital administers do not permit therapists to practice outside the hospital (17d)*” and “*as our hospital’s policy, going out with patients is not preferred. (62a)*” They were restricted by the administration in the hospital.

B) Imperfections in the social system

In some cases rehabilitation outside the hospital was restricted because it is not profitable owing to the lack of health insurance coverage, for instance, “*because rehabilitation outside the hospital is not covered by health insurance (3a)*” and “*practice of public transportation give little profit (23c).*”

The other barrier was problems of guarantee if any accidents would be happened. This category was extracted from the following representative label, “*if any accidents like falling and medical emergency occurred, it will be difficult for our hospital to guarantee patients. (50d)*” The restriction was caused by problems in our social system regarding insurance and guarantee system.

2) Specific factors of the task

Fifty respondents (60.2%) pointed out that there were specific factors involved in practicing public transportation use. This category had four third-level categories: C) high risk of practice (30 labels), D) problems with environment around the hospital (19 labels), E) problems of manpower and time (28 labels), and F) Not

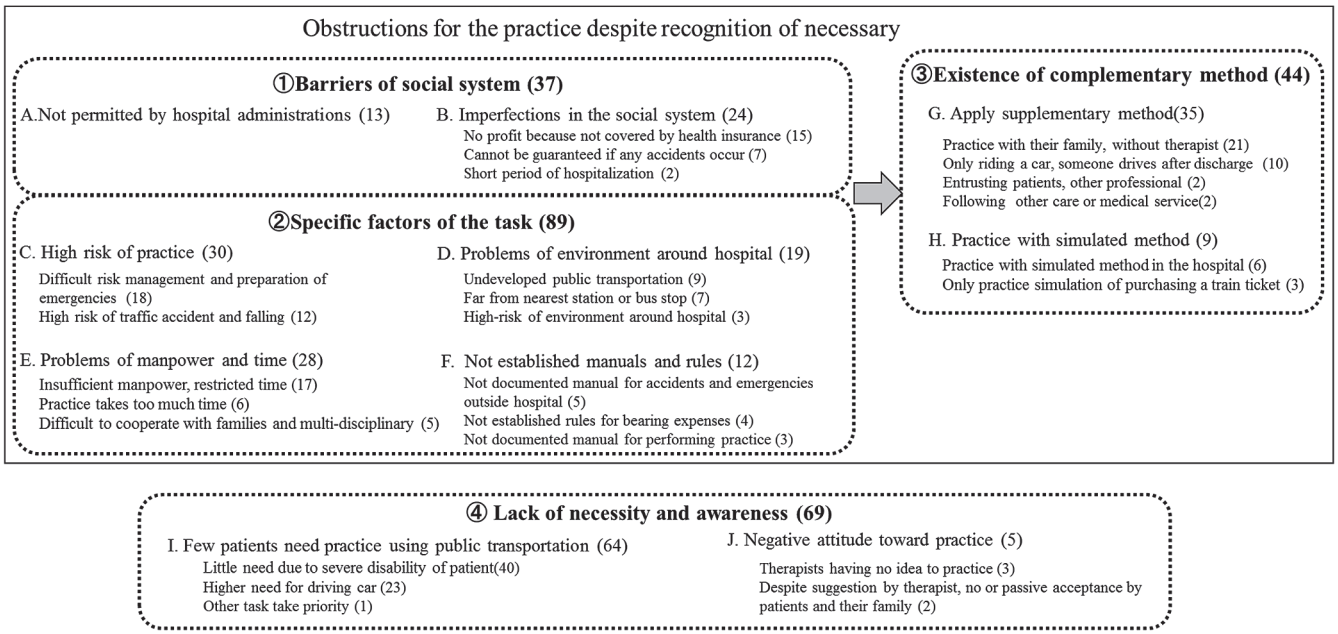

Fig. 1. Qualitative analysis of reasons not to practice using public transportation.
Note: Parentheses in the table indicate number of label

established necessary manuals and rules (12 labels).

C) High risk of practice

This category included high risk of traffic accidents and falling, emergency for patients outside, and difficult to cope with accidents and emergencies away from the hospital. A respondent suggested that "*we are worry about how to cope with an emergency away from our hospital. It is would be difficult (50c).*" Therefore, many therapists recognized that the practice had a lot higher risk factors than those in the hospital.

D) Problems of environment around hospital

Some occupational therapists felt that there were barriers regarding the environment around the hospital, such as undeveloped public transportation, long distance from station or bus stop, and danger around the hospital. For example "*we spend a lot of time waiting for a train because only one train comes every hour (55c)*" and "*the pavement to the station is narrow and bumpy around our hospital (19c).*" Therefore, the environment around the hospital affected whether practice was performed or not.

E) Problems of manpower and time

It took extensive manpower and time to practice using transportation in several hospitals. Examples of their responses were "*impossible to come back to the hospital after practice on the train within the given rehabilitation time (17a)*," *taking too much time for practice. (9a)*," and "*we have more number of patients than therapists (30b)*." Using transportation takes more time than usual rehabilitation in their hospital. Moreover, a shortage of manpower restricted the practice of using transportation.

F) Not established manuals and rules

Some hospitals have not made necessary manuals and rules such as practice protocol, payment for the cost of transportation, and countermeasures for accidents or emergencies outside. The representative opinions were, "*in our hospital, rules for the practice haven't been established yet (81a)*" and "*there is a problem: who will pay for the expense of using transportation? Sometimes therapists pay the fee by themselves (78g).*"

3) Existence of complementary method

Forty-four respondents (41.0%) mentioned using a complimentary method as the reason for not practicing public transportation use. Complementary methods included two lower categories: G) applying supplementary method (35 labels) and H) practice with simulated method (9 labels).

G) Applying supplementary method

Instead of the actual practice by therapists a supplementary method was used. The representative labels were, "*when an inpatient returns home for a while, we ask his or her family to use the transportation that will be used after discharge and to assess their behavior*

with a checklist (19f)" and "*after discharge, we ask home-visiting therapists to follow-up with them (63b)*." The therapists made use of the patients' family, other service, or other professional if they had not given their patient practice.

H) Practice with simulated method

Without riding a train or a bus, simulated activities are also used, such as "*in the rehabilitation room, we assess a patient using steps as high as those of the bus entrance (55e)*" and "*we took a patient to the nearest station to pretend to buy a ticket as a practice (12c)*." Patients did not actually ride public transportation but the therapist simulated similar conditions for their patients.

4) Lack of necessity and awareness

Thirty-nine respondents (47.0%) answered that practice was not necessary and it had a lower priority than other necessary things. In this category, therapists, patients and their families thought that practice was not necessary: I) few patients need practice using public transportation (64 labels) and J) negative attitude toward practice (5 labels).

I) Few patients need practice using public transportation

Patients did not need to practice because "*our patients are in such a bad medical condition that they cannot go out and they are old aged (59b)*" and "*driving a car is the main form of outdoor mobility so in this area it is more necessary than using public transportation (53a)*." The demand for public transportation depended on the area. In a rural area, driving a car is a more common form of outdoor mobility compared with using public transportation.

J) Negative attitude toward practice

Some answers insisted that therapists, patients, and families had a negative attitude toward the practice. Some examples were, "*we have never thought practicing use of public transportation in our hospital (26e)*" and "*patients and families refused the suggestion to practice from their therapists. (71c)*."

Discussion

We studied the reasons for not practicing the use of public transportation using a postal survey. Interviews are often used in qualitative studies as a study method [18]. Alternatively, few researches use a postal survey. While thinking of reasons for not practicing the use of public transportation before the present study, we hypothesized various reasons that depended on the area and site in which the hospitals were located. Therefore, the survey was not performed for a widespread area in major urban places of Japan. Moreover, a postal survey is one directional communication and can sometimes cause misunderstanding. In the present study, we omitted data if it was difficult to interpret the meaning. However, we believe that the more than 200 labels in this study are enough to analyze reasons not to practice.

The result suggested that one of the reasons was a barrier in hospital administration and social system policies such as health insurance and guarantee for accidents outside of the hospital. In Japan, it is unclear whether we can or cannot apply health insurance to occupational therapy cost when it is performed outside of the hospital site. It could have a dramatic effect on the judgment of occupational therapists for performing the practice. To resolve these issues it would be necessary to clarify the evidence of practice. Logan et al. [9] reported a significant effect of home-based occupational therapy for people with stroke for the purpose of outdoor mobility. Alternatively, there has been no evidence regarding practicing the use of public transportation for inpatients. Therefore, it would be important to verify the practice effect and to appeal the necessity of the practice to provide appropriate occupational therapy corresponding to patient needs.

Some factors in the hospital affected the pros and cons of practice. For example, the number of therapists and number of hospital beds was correlated with the extent of practice. These results suggest that a large population of therapists and large hospitals can easily make time and establish a manual for practice. Hiring more therapists and making a manual is not easy but is required for practicing the use of public transportation.

Hospital environment was one of the reasons for not practicing. A previous study suggested that the perceived neighborhood environment affected the amount of walking in the elderly [19]. Infrequent public transportation, such as one train in one hour, was also one of the barriers. Ogawa et al. [12] found that making courses for the practice helped to shorten the duration of the practice. Therefore, setting up the courses and departure time would solve the problem, particularly in Japan as most of the trains operate on time. Considering that practicing actual condition leads to reacquired occupations, it would be essential to remove these barriers.

In cases where therapists could not practice using public transportation, simulation of the practice close to "real life" in the hospital was used instead of actual situation. Doig, Fleming, Cornwell and Kuipers [20] reported that rehabilitation in an actual situation such as patients' home was more satisfying and effective from a

quantitative study analyzing patient interviews. Recently, home-based and community rehabilitation has been examined because it may effectively enhance community reintegration [21−23]. Therefore, actually practicing using public transportation would be close to real life, for example at home, and more effective for patients to learn the motion and to be motivated. However, it would be necessary to show the effectiveness of actually using public transportation compared with the simulated practice.

The results of this study are not always generalizable because all of the subjects worked on sub-acute rehabilitation hospital in urban community of Japan. Therefore, future studies may seek to explore the present situation in other setting such as an acute hospital and home-visiting rehabilitation. We found many reasons for lack of practice; however, we also have limitations of this study that need to be addressed, for example, the social system and difference in environment surrounding public transportation , which depends on the country and area, e.g., urban or rural [5]. In some countries and areas, driving a car would be more important than using public transportation [24, 25]. Alternatively, 28.7% of people use public transportation for outdoor mobility in the metropolitan area of Japan [16]. Therefore, in these regions, the quality of life of people with disabilities who could not use these public transportations would be affected. The goal of rehabilitation has been described to be to "maximize the patient's role fulfillment and his independence in his environment, all with the limitations imposed by the underlying pathology and impairments and by the availability of resources" [26]. Occupational therapists should resolve the inhibiting factors of the practice and facilitate the use of public transportation for the elderly and those with a disability to acquire their important occupations.

Conflicts of interest

The author declares no conflict of interest.

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■ORIGINAL ARTICLE

The effect of the challenging two handed rhythm tapping task to DLPFC activation

Mutsumi Abiru[1], Hiroshi Sakai[2], Yasuhiro Sawada[3], Hiroshi Yamane[2]

[1] Human Health Science, Graduate School of Medicine, Kyoto University, PhD program
[2] Human Health Science, Graduate School of Medicine, Kyoto University
[3] Department of Occupational Therapy, College of Life and Health Science, Chubu University

Abstract: Using functional near infrared spectroscopy (fNIRS), we have been researching the effect of musical attention control training (MACT) on the prefrontal lobe, which is involved in attention control. We detected significant dorsolateral prefrontal cortex (DLPFC) activation during music-based tasks that included "dual task" elements. In this study, to elucidate which musical elements influence DLPFC activation, we focused on the effects of tempo of both handed Rhythmic tapping tasks (RTT), which including "dual task" elements. RTT with 3 different tempos, the easy (E) (slow tempo), intermediate (I) (moderate tempo), and difficult (D) (fast tempo) tasks, were developed. Then, the activation of the DLPFC was measured during each task. Our results detected a significantly stronger DLPFC activation during the (D) task than during the (E) task ($p < 0.01$) or the (I) task ($p < 0.01$). These results indicate that the difficulty of RTT can be adjusted by altering the tempo. Music-based tasks could be useful for cognitive training programs, even those for poorly motivated people with severe attention deficits through changing the difficulty level by changing the tempo.

Keywords: Music, Dual task, DLPFC, Rhythm, Attention functions, Cognitive rehabilitation

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Introduction

Higher brain dysfunctions, such as attention deficits, memory deficits, and executive function deficits can inhibit activities of daily living and prevent individuals from returning to employment. In particular, executive functions can cause problems with reintegration into society [1]. In order to perform executive functions appropriately, individuals have to be able to efficiently and appropriately recruit attention functions, which are considered to form the basis of all cognitive functions [2]. Therefore, improving attention functions is essential to the success of rehabilitation [3].

Attention processing training (APT) mainly involves searching tasks and is considered to be a typical training method for attention function deficits [4]. Although the efficacy of these methods has been verified, sufficient motivation and certain attention functions are required to perform them. Therefore, training methods that motivate the participants to focus on the task and whose difficulty levels can be adjusted for each participant are required.

It is reported that music tasks that mainly involve auditory stimulation promote attention functions more efficiently than tasks that mainly involve visual stimulation [5]. Therefore, music-based tasks could promote attention functions more efficiently than conventional training tasks, which mainly involve visual searching tasks. Moreover, music-based tasks motivate the participants more than other desk-based training tasks, and this is especially true for people with low self-motivation, attention function deficits, and severe cognitive deficits. Furthermore, Music-based tasks would also be easy to adjust the difficulty levels by changing the tempo and rhythm of the music involved.

Thus, we have been researching the effect of music on attention function through both clinical and basic studies.

In healthy participants, we have been researching the relationship between the characteristics of musical tasks and cerebral blood flow (CBF) by measuring the

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Corresponding to: Mutsumi Abiru, Human Health Science, Graduate School of Medicine, Kyoto University, 53 Kawaramachi Syougoin sakyou-ku Kyoto city, 606-8397, Japan
e-mail: muchanabiabi@yahoo.co.jp
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change in CBF in the dorsolateral prefrontal cortex (DLPFC) region of the prefrontal lobe, which controls attention functions, by using functional near infrared spectroscopy (fNIRS) [6]. In this study, we found that musical tasks involving "dual task" elements, such as singing during a rhythmic tapping task (RTT), strongly influence DLPFC activation [6]. However, we are not sure which elements of music, such as melody, tempo, harmony, and rhythm etc, influence DLPFC activation in fact. Among those basic elements of music, we thought rhythm can be easily understood for everybody since it is easy to play even by individuals without any musical experience and easy to include dual task elements. Therefore, we focused on rhythm to study. As basic rhythm pattern, bilateral rhythmic tapping tasks (RTT), which include dual task element by using both hands differently, was selected. Then, the difficulty level of RTT was adjusted by changing its tempo.

In this study, we researched the relationship between activation of the DLPFC region and the difficulty of rhythm-based dual tasks by adjusting the tempo in a step-by-step manner as a means of altering its difficulty level.

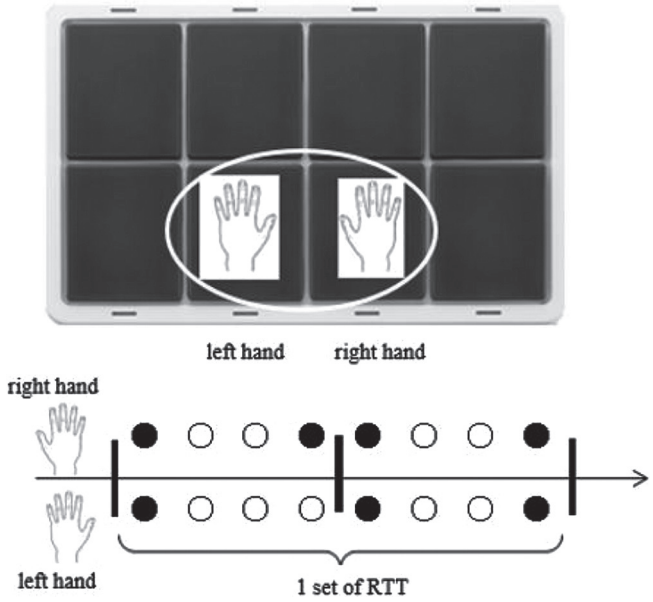
Methods

1. Participants

Thirty healthy participants with no physical or mental problems (9 males, 21 females; mean age: 22.03 ± 2.39; 26 right-handed), who met requirements in the following preliminary test, were selected from 34 undergraduate students, who applied in this study.

The preliminary tests by using the basic rhythmic tapping task (RTT) were implemented before this study since the difficulty level of rhythm varies from person to person. The basic RTT are shown in Fig. 1-a). Four participants were excluded in the preliminary test due to: 1) failure to reach 90% success rate on the easy task (E) even after 3 minutes' practice or 2) ability to easily complete the difficult task (D), such as experienced musician.

Informed consent was acquired before study procedures began. This study was approved by Kyoto University Graduate School and Faculty of Medicine, Ethics Committee (C593). All participants were required to sign consent forms, which explained the purpose, methods, benefits, and disadvantages of this study and that their participation was voluntary, before participating in this study.



a) Octapad Digital Percussion Pad (ODPP) and the basic rhythm pattern of Rhythmic tapping task (RTT)

[Easy task (E)]	30 sets of RTT / min.
[Intermediate task (I)]	60 sets of RTT / min.
[Difficult task (D)]	80 sets of RTT / min.

b) Each level of RTT

Fig. 1. a) Upper part of Figure 1-a) showed an electronic rhythm instrument, an Octapad Digital Percussion Pad: ODPP (Roland SPD-30), was set up in front of the participant. The ODPP had been set up so that the right and left sides produced different sounds. The participants just hit the 2 pads of ODPP which circled with white line. The lower part of Figure 1-a) showed the basic rhythm pattern of RTT. ●Indicates that an examiner hits the percussion Pad and ○ indicates the examiner does not hit the ODPP. The basic rhythm pattern of RTT was the same for all levels.
b) 30, 60, and 80 RTT sets were performed per minute for the easy (E), intermediate (I), and difficult task (D), respectively.

2. Rhythmic tapping task (RTT)

The basic rhythm pattern of RTT is shown in Fig. 1-a). ●Indicates that an examiner hits the percussion Pad and ○ indicates the examiner does not hit the percussion Pad. To select the basic RTT, the RTT, which is the most participants were able to perform perfectly at a slow tempo but difficult with a faster tempo, was selected as RTT preliminarily.

Three different difficulty levels of RTT, were created according to the accuracy rate data obtained in the preliminary experiment:

(1) The easy task (E), in which 30 sets of the RTT were performed per minute at an accuracy rate of approximately 100%.
(2) The intermediate task (I), in which 60 sets of the RTT were performed per minute at an accuracy rate of approximately 80%.
(3) The difficult task (D), in which 80 sets of the RTT were performed per minute at an accuracy rate of approximately 50% (Fig. 1-b).

The all participants watched each level of RTT task (E, I, and D) being performed on a monitor, which set up in front of them. In the monitor, the examiner's hands were visually and auditory showed, as an example. They then performed each task on an electronic rhythm instrument, an Octapad Digital Percussion Pad: ODPP (Roland SPD-30). ODPP had been set up in front of the participant so that the right and left sides of the ODPP produced different sounds. Preliminary sufficient practice of each task was implemented before the measurement of fNIRS. With watching the monitor, the participants then performed each task on the ODPP, while fNIRS measurements were obtained (Fig. 2).

To avoid the learning process affecting their results, the researchers ensured that all participants understood the basic rhythm of the RTT and had practiced it fully before the experiment.

3. The percentage of correctly played RTT

In this study, gradual blood flow changes during each task (60 seconds) and the percentage of correctly played RTT were measured simultaneously. Calculation of the percentage of correctly played (E), (I), and (D) RTT tasks was recorded by a video camera. The number of correct RTT responses was counted by reviewing the video records after the experiments. As described in Fig. 1-a), each RTT set was composed of 7 beats (○ or ●), and the beats to be played with the right and left hand were indicated by (○) and (●), respectively. All levels of RTT were performed with watching the monitor which showed the performance of examiner. Therefore, as a criterion of correct RTT, when all 7 beats were not delay and/ or when the number of RTT sets that were played correctly from example RTT showed through the monitor, the RTT were counted as the correct RTT set. Then, the number of RTT sets that were played correctly per minute was divided by the total number of RTT played per minute for each task level. Then, the quotient was multiplied by one hundred.

4. Prefrontal cortex measurement fields

It is reported that a circuit involving the DLPFC,

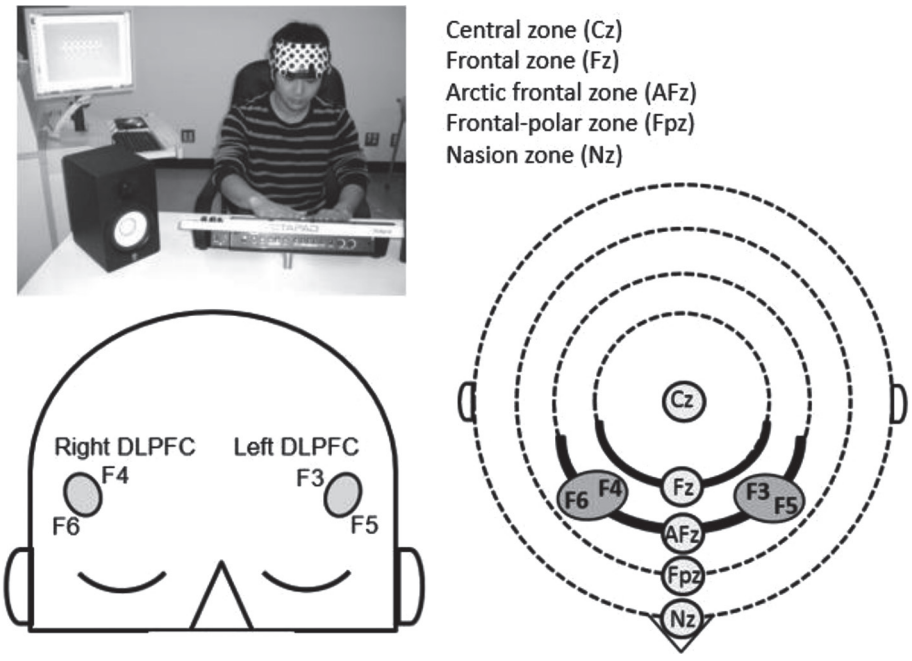


Fig. 2. Measurement environment and the relationship between the locations of the probes and areas of the brain.

prefrontal lobe, and cerebellum controls the accuracy of movements [7]. In this experiment, it was important that the participants implemented the task precisely as instructed to activate attention control functions. Therefore, we expect a circuit involving these areas of brain. However, we had to narrow down the target area of the brain since it is hard to observe the entire brain using our fNIRS system. Therefore, we focused on the DLPFC, which is considered to control movement accuracy through both motor control and cognition [8, 9].

5. Measurement of prefrontal area activation

The activation of the prefrontal lobe during each task was compared by assessing the changes in brain blood flow induced by using fNIRS. We used the FOIRE-3000 fNIRS system (Shimazu Corporation, Japan). The units of this fNIRS are shown as arbitrary unit (a.u.). The different size and shape of each participant's head changed the length of the light path. Therefore, the relative changes in the oxyHb concentration in the resting stages were set as 0 a.u. The stage of just before the each task was set as a criterion of resting stages. Through these quantitative measurements, the validity of comparison between subjects was reported [10]. The fNIRS measurement interval was set at 115 ms. The lowest line of probes was horizontally aligned with the frontopolar point [Fpz] of the International 10-10 System of Electrode Placement, which is the standard system for electroencephalographic measurements. Three probes each were placed on the right and left of the [AFz], and then a second line of probes was placed 30mm above the initial line of probes. Therefore, a total of 14 probes (19 channels); i.e., two rows of 7 probes, were employed (Fig. 2).

Brodmann area 46, which is involved in the central executive system of working memory, was chosen as the target area within the DLPFC. However, the size and shape of each participant's head were differed; therefore, it was difficult to confirm the area of the brain that had been activated using a head chart. Thus, the F3-F5 area (left DLPFC area) and F4-F6 area (right DLPFC area) were subjected to analysis since Okamoto et al. [11] reported that these areas were considered to be closest to Brodmann area 46.

In addition, the channels in each area displayed the same waveforms. Therefore, the channel that displayed the lowest amount of noise among nearby channels was selected for the analysis (Fig. 2). Therefore, once the target channels for each participant were set, it did not change among the different tasks for the same participant.

The change in the oxyHb concentration was used as a measure of neural activation, and the mean oxyHb concentration changes induced by each task were compared. Since the change in the oxyHb concentration indicates the degree to which a particular brain region is activated, a greater change in oxyHb indicates stronger activation of the relevant brain area [10].

It would have been difficult to set up a control task since various factors influence DLPFC activation during simple tasks (or resting). Minati et al. [12] reported that the first trial could easily have been influenced by mental tension and thus produced different results from the procedural trials. Therefore, we used the first trial as a dummy trial (DT) (tapping with the right and left hand in an alternating manner). The tempo of DT was same as E-level. Thus, the DT was set to help participants get used to the research procedure. Then, the accuracy rate and blood flow data were compared between the (E), (I), and (D) tasks.

A block design (10 sec. (rest) – 60sec. (task) – 10 sec. (rest)) was used for the measurement sessions. A total of 4 blocks (60sec. × 4 blocks; total: 240 sec), which were composed of one DT and the three RTT tasks (E, I, and D) were performed one after the other (Fig. 3).

To avoid learning effect and fatigue, preliminary sufficient practice of each task was implemented before the measurement of fNIRS. Since the three tasks (E, I, and D) were all composed from the same basic RTT, and the difficultly level of each task (E, I, and D) was determined by its tempo. In addition, to avoid the influence of task's order, 30 participants were allocated to 3 groups (Pattern 1, 2, and 3), which first order was different each other (Fig. 3).

6. Analysis of data

The collected blood flow data were systematically transformed according to standardized methods using the analysis software included with the fNIRS system. Then, the data for each task were saved in text format and opened in MS Excel. The point, when the DT finished, was revised to [0] on the total data line, and then mean values were calculated.

SPSS version 20 (IBM, Japan) was used for statistical analyses ($p < .05$). Friedman test was used for the percentage of correct played RTT in each task. Two-way ANOVA was used for the comparison of the brain activation and order. Tasks and orders were as fixed factor. Activations were as dependent factor. As multiple comparison, Tukey's test was applied.

7. Limitation of fNIRS

The fNIRS data would have been influenced by various factors other than the tasks. Therefore, the tasks and data collection would have to have been performed in a

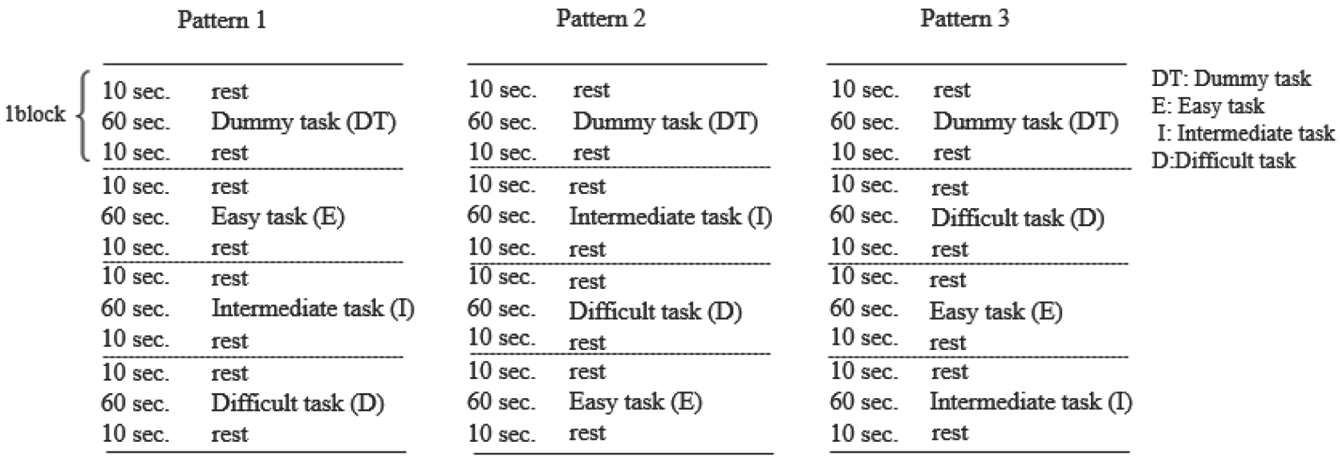


Fig. 3. The order of the task.

strictly controlled manner in order to allow the investigators to determine which factors were associated with each change detected by the fNIRS system. However, it is unlikely that data obtained from such a strict research environment would be applicable to clinical situations. Therefore, in this study, creating a research environment that closely mirrored the clinical setting was considered to be the highest priority.

In addition, unlike other measurement methods, such as fMRI, there are no well-established methods for analyzing fNIRS data. The method we employed in this study was chosen because it allows quantitative comparisons of fNIRS data. However, the spatial resolution of fNIRS is lower than that of fMRI, and there are difficulties with the strict localization of brain areas, such as locating individual Brodmann areas of the brain. Furthermore, it is impossible to compare fNIRS data between participants since the distance from the surface of the head to the cortex of the brain and the percentage of light absorbed differs depending on the angle of the device. However, after considering these limitations we decided to use fNIRS for our measurements due to its advantageous characteristics, such as the reduced burden it places on participants and the fact that it allows measurements to be obtained continuously during tasks involving movement.

Results

1. The percentage of correct played Rhythmic Tapping Task (RTT) in each task

The percentages of correctly played RTT in each task are shown in Fig. 4. The median was 99 (range from 92 to 99) in (E), and 98 (70 to 98) in (I), and 83 (26 to 92) in (D).

In the Friedman's test, the percentages of correctly played RTT were significantly different ($p < 0.01$), and following paired test was also significantly different between (E) and (I) ($p < 0.01$), (E) and (D) ($p < 0.01$), as did the comparison between (I) and (D) ($p < 0.01$) (Fig. 4).

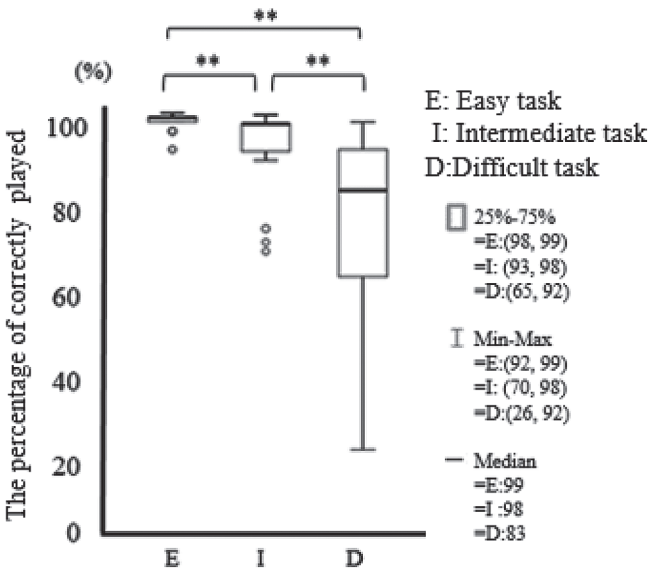


Fig. 4. The percentage of correctly played rhythmic tapping task (RTT). The box plot of the bottom and top of the box indicate the first and third quartiles, and the band inside the box indicates the median. Then ends of the whiskers represents the minimum and maximum value within the half time of the top and bottom value of box. ○ indicates outlier. $^{**}p < 0.01$.

2. A representative participant's waveform data of each task and pattern

A representative participant's waveform data for the oxyHb changes observed during each task (E, I, and D) on each pattern (1, 2, and 3) are shown in Fig. 5. As

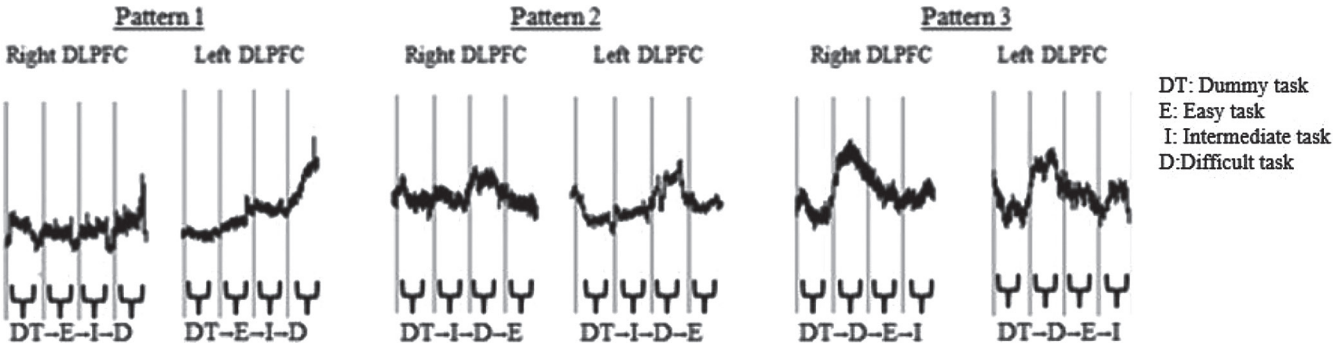


Fig. 5. Waveform data of DLPFC for the OxyHb changes of a representative participant observed during each task.

the tempo of the rhythm increased, the waves associated with it became a larger-mountain-shape, and increasing the tempo also resulted in wider activation of both the right and left DLPFC, regardless of the order in which the tasks were performed (patterns 1, 2, and 3).

3. Comparison of the brain activation induced by each task

The comparisons of the brain activation induced by each task are shown in Fig. 6.

In the Left DLPFC, the mean oxyHb concentration ± standard error of mean (SEM) of E task was 0.18 ± 0.16 a.u. in (pattern 1), 0.14 ± 0.27 a.u. in (pattern 2), and 0.58 ± 0.39 a.u. in (pattern 3). I task was 0.54 ± 0.13 a.u. in (pattern 1), 0.45 ± 0.16 a.u. in (pattern 2), and 0.35 ± 0.33 a.u. in (pattern 3). D task was 1.93 ± 0.14 a.u. in (pattern 1), 1.59 ± 0.27 a.u. in (pattern 2), and 1.57 ± 0.39 a.u. in (pattern 3). The main effect of task was statistically significant ($F(2,81) = 24.58$, $MSE = 17.60$, $p < 0.01$, $\eta^2 = 0.37$). The main effect of order was not significant ($F(2,81) = 0.30$, $MSE = 0.22$, $p = 0.74$, $\eta^2 = 0.01$). The interaction of task and order was not significant ($F(4,81) = 0.61$, $MSE = 0.43$, $p = 0.66$, $\eta^2 = 0.02$) (Fig. 6). The multiple comparison demonstrated significant differences between E and D ($p < 0.01$), I and D ($p < 0.01$), but not between E and I.

In the right DLPFC, the mean oxyHb concentration ± SEM of E task was 0.40 ± 0.12 a.u. in (pattern 1), 0.93 ± 0.30 a.u. in (pattern 2), and 0.37 ± 0.32 a.u. in (pattern 3). I task was 0.80 ± 0.13 a.u. in (pattern 1), 0.70 ± 0.18 a.u. in (pattern 2), and 0.12 ± 0.42 a.u. in (pattern 3). D task was 2.05 ± 0.11 a.u. in (pattern 1), 2.08 ± 0.22 a.u. in (pattern 2), and 1.67 ± 0.24 a.u. in (pattern 3). The main effect of task was statistically significant ($F(2,81) = 31.57$, $MSE = 19.05$, $p < 0.01$, $\eta^2 = 0.41$). The main effect of order was not significant ($F(2,81) = 0.35$, $MSE = 0.21$, $p = 0.71$, $\eta^2 = 0.01$). The interaction of task and order was not significant ($F(4,81) = 2.20$, $MSE = 1.33$, $p = 0.08$, $\eta^2 = 0.06$) (Fig. 6). The multiple comparison demonstrated significant differences between E and D ($p < 0.01$), I and D ($p < 0.01$), but not between E and I.

Discussion

The relationships between the percentage of correctly played RTT and DLPFC activation in each task

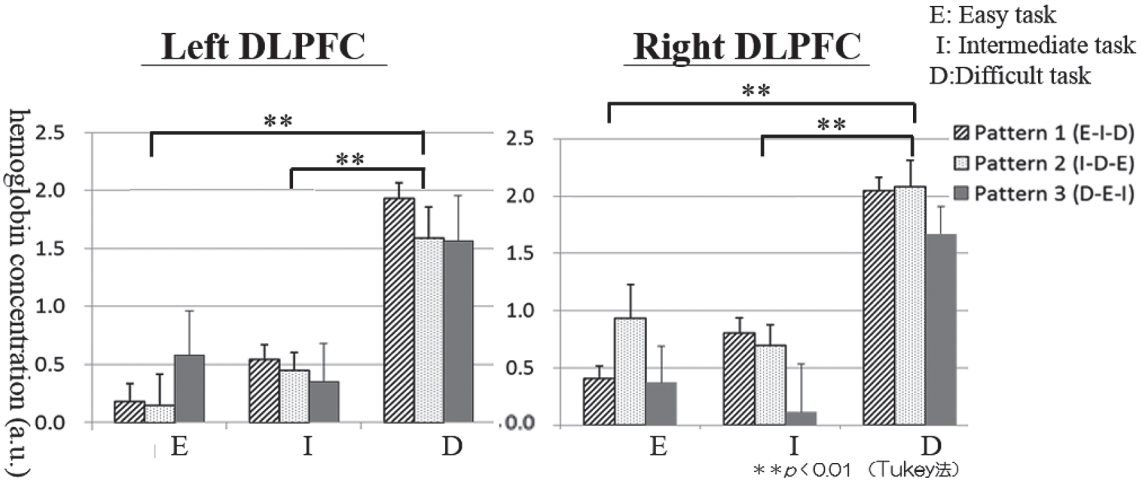


Fig. 6. The mean OxyHb concentration changes during each task. Error bar indicates SEM.

are discussed below.

In a comparison of the percentages of correctly played RTT between each task, significant differences were detected between (E) and (D) ($p < 0.01$), (E) and (I) ($p < 0.01$), and (I) and (D) ($p < 0.01$).

In a comparison of the DLPFC activation induced by each task produced the almost same results except between (E) and (I). In a comparison of (E) and (I), there was no significant difference between the activation of the right or left DLPFC. However, in comparisons of (E) and (D) ($p < 0.01$), and (I) and (D) ($p < 0.01$), significantly increased activation was observed in both the right and left DLPFC individually during the more difficult tasks (D) (Fig. 6).

It is considered that the activation of DLPFC, observed in this study, is induced by executive attention system of working memory, since many studies have reported that the increase of simple repetitive movements does not activate DLPFC [13−16].

Due to the characteristics of fNIRS, it is hard to derive rigorous conclusions from our data; however, in this restricted situation, we would like to consider the following topics: how the characteristics of each task activated the DLPFC, why both the right and left DLPFC were activated, and the challenges for future clinical research thrown up by our findings regarding the relationship between the percentage of correct RTT and DLPFC activation during each task.

1. The characteristics of the rhythmic tapping task (RTT) that activated the DLPFC

The RTT used in this study required the participants to simultaneously tap different rhythm with their right and left hands, which indicates that the basic RTT was included "dual tasks" element in this study. According to Low et al. [17], "dual tasks" activate the DLPFC by gradually increasing the workload placed upon it. In this study, the percentage of correctly played RTT was lower in (D) than (E) or (I), even though all tasks included "dual task" elements. This indicates that (D) increased the workload by faster the tempo, and which leads more activation of the DLPFC.

In addition, Shallice [18] explained that the early stage of learning (in high difficulty situations) activates the supervisory attention system (SAS), which controls the precise execution of tasks through active attention control, and then activates the DLPFC. In this study, we considered that (D) also activated the SAS since (D) required the participants to produce accurate movement execute the RTT precisely under the situation of the faster the tempo which requires active attention control.

Therefore, we considered that (D) activated the DLPFC, which is involved in the executive attention system and the SAS, due to its characteristic of the controls the precise execution of tasks through active attention control.

2. Why were both the right and left DLPFC activated?

Vogh et al. [19] reported that the main roles of the left DLPFC are observing new information and making preparations for movement and that the main role of the right DLPFC is supervising movement during tasks, such as playing the guitar. In this study, the left DLPFC would have been activated when the subjects were obtaining information about the new rhythm through observing the monitor and preparing for tap the rhythm, and the right DLPFC would have been activated when the subjects were supervising their tapping themselves during each RTT.

In addition, Hatakenaka et al. [20] reported that the early stage of learning new movements (in difficult situations requiring concentration) is considered to involve strong activation of the entire prefrontal lobe. In this study, (D), which most strongly activated the DLPFC, required the participants to tap 80 sets of the RTT per minute. In other words, (D) involved the greatest amount of complex movements, in addition to observing, preparing, and supervising of the movement, in the strict time regulation. Therefore, it indicated that the combination of complex motor learning, executive attention system of working memory in the certain time regulation for (D) also resulted in the strong activation of both the right and left DLPFC.

However it was impossible to compare the each task's value of right and left DLFPC directly since the individual probe was not measured same value between right and left DLPFC in measurement method of NIRS in this study. As challenges for the future, it is required to consider direct comparison of right and left DLPFC by setting basic ratio between frontal lobe and temporal lobe.

3. Summary and clinical challenges for the future

According to the results of this study, tasks with a faster tempo and not high accuracy rate activate the DLPFC more than slower and easier tasks. It is considered that tasks that require great focus to increase accuracy would activate the DLPFC, which is involved in the executive attention system of working memory and the central executive system of the SAS, more than tasks that are so easy that they quickly become routine.

During the performance of (D), in addition to observing new information and preparing for movement, which engaged the left DLPFC, and the element of supervision, which engaged the right DLPFC, the increased amount of motion also resulted in the strong

activation of both the right and left DLPFC.

Nittono et al. [21] reported that the capacity of working memory, which controls the DLPFC, varies from person to person although tasks with a high difficulty level activate the frontal lobe more strongly than tasks with a low difficulty level. Thus, to ensure that the DLPFC is effectively activated in each participant, it is important to set a difficulty level for them. However, if the task was too difficult to perform, even after making an effort, they would just give up. Therefore, it is important to set the task which is comfortably difficult for each participant.

To adjust the difficulty level in "dual tasks" for each participant, music-based tasks would be easy to do. It is because music-based tasks are easy to add and decrease the element to adjust, such as the tempo or whether they only require one hand, etc. This make possible therapists to develop a task that most participants will be able to perform with effort comfortably.

The difficulty level in this study was set by acceleration of tempo of RTT but that also lead the increase of the amount of motion to beat RTT in each task. Therefore it was actually not clear which factor increases the activation of DLPFC, whether it was the amount of motion or acceleration of tempo. Therefore, re-examining the task setting would be required in the future. Although simple comparison between the amount of motion and acceleration of tempo would not make sense due to the characteristic of DLPFC.

In addition to adjusting the difficulty level of a task, individual personality traits and attitudes toward tasks also influence DLPFC activation. For example, some people work through tasks at maximum effort, even during very easy tasks; on the other hand, other people employ the minimum effort, even during difficult tasks. Therefore, to decrease the effects of such factors, it is important to observe individual personal traits. Preliminary observations would help to recognize individual personal traits, such as the type of directions that would encourage individual participants to expend a sufficient amount of effort or focus on a task. It is important to do as much as possible to adjust the difficulty levels of tasks so that they match the personality traits of the participants.

In this study, the participants were all young and healthy. Therefore, our findings might not be applicable to the clinical setting because the difficulty level of each task would also be influenced by the disease status of the participants, such as whether they were suffering from higher brain dysfunction or dementia. With clinical populations it would be necessary to adjust the difficulty level of attention training tasks for each participant in the future.

Conclusions

Training programs for higher brain dysfunction have to be performed in a low stress environment and be enjoyable and interesting. Music is stimulating, even for poorly motivated individuals with low cognitive function. In addition, it is comparatively easy to set the difficulty level of music-based tasks for each participant by adjusting the tempo, rhythm, and/or the number of hands, etc. Therefore, we consider that music-based tasks would be useful for frontal lobe rehabilitation since it is motivating, and easy to set the comfortable difficulty level to stimulate this area of the brain more than other easy fun tasks.

Through continuous clinical research, we would like to develop an attention-training program that is suitable for a wide range of participants and makes use of the effects of music on the prefrontal lobe, which is closely involved in attention functions.

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■ORIGINAL ARTICLE

Clinical response of dynamic splint using functional scales for the extension contracture of the metacarpophalangeal joint

Jun Nakayama[1], Mituru Horiki[2], Kakuro Denno[2], Kazunori Ogawa[3], Hisao Oka[4], Kazuhisa Domen[5]

[1] Department of Rehabilitation, Kansai Rosai Hospital
[2] Department of Orthopaedics Surgery, Kansai Rosai Hospital
[3] Daiya Gum Industry.CO
[4] Graduate School of Health Sciencse, Okayama university
[5] Department of Physical Medicine and Rehabilitation, Hyogo College of Medicine

Abstract: Collateral ligament shortening causes extension contractures of the metacarpophalangeal (MCP) joint, and dynamic flexion splinting (DFS) has been widely used to treat these contractures; however, there are various problems with these approaches. We developed a novel, pneumatic-type dynamic traction and flexion (DTF) splint to solve these problems. Twenty-one patients were treated with either the DTF or DFS for 8 weeks. Every 2 weeks, the average MCP joint flexion angle, total active motion (TAM), grasp strength, and pain scores were assessed. The flexion angle, in the DTF, was significantly greater than that in the DFS, starting after 6 weeks of treatment ($p < 0.05$). Similarly, the TAM results were significantly better following DTF treatment. Compared to treatment with DFS, our results showed that DTF treatment promoted earlier recovery of joint flexion angle and whole finger function in patients.

Keywords: extension contracture, dynamic splint, MCP joint

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Background

Because finger function is important for holding and pinching objects, the metacarpophalangeal (MCP) joint is critical for the proper functioning of the hand. Contracture of these joints, often resulting from trauma and burns [1, 2], cause significant disorders in the activities of daily living (ADL), including eating, excretory functions, grooming and bathing. Thus, treatment of this type of contracture is extremely important for regaining normal hand function. Contractures of the MCP joints are common clinical conditions [3] that may be caused by shortening of the collateral ligament. Since the MCP joint is associated with a collateral ligament, unlike other joints, regaining flexibility of the collateral ligament is necessary to improve the joint's range of motion. However, treatment of severe contractures is often very difficult.

Appropriate treatment of this type of contracture is extremely important. The therapy used to treat the joint contracture should be both integrative and problem-focused. Therefore, the therapist should avoid worsening the joint problem through inappropriate rehabilitation, such as long-term fixation and malpositioning of the joint after a fracture. Pressure therapy, active mobilization, and passive mobilization, using remedial orthotic positioning, should be started as soon as a problem is diagnosed. Continuous stretching is an effective treatment for these contractures [4], and the treatment efficacy is improved through the use of a dynamic orthosis [5−7], which is a well-accepted modality used to regain joint motion in an injured hand [8]. The clinical success of dynamic orthotic positioning is better and results in less joint stiffness if the interval between injury and treatment is kept short [9].

The dynamic flexion splint (DFS-splint) has been widely used for the treatment of MCP joint extension

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Corresponding to: Jun Nakayama, Department of Rehabilitation, Kansai Rosai Hospital, 69-1, Inabaso, Amagasakishi, Hyogo, 660-8511, Japan
e-mail: nakayama-kanrou.hp@live.jp
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contractures [10, 11]. This conventional type of flexion splint can, however, negatively impact the articular surface of the joint, leading to pain when the finger is flexed for an extended period [3]. As a result, range of motion improvements are difficult to obtain [11]. Therefore, we devised a new dynamic traction splint using curved rubber, also known as pneumatic artificial muscle (PAM), as part of a novel dynamic splint. PAM is used for rehabilitations involving remedial neuromuscular and gate exercises [12−14], including for providing power assistance to paralyzed muscles [15]. Also, PAM is used in conjunction with various joints as an adjunct for weak or paralyzed muscles, according to preliminary research [16]. However, the use of PAM splints has not been previously reported for improving joint contracture.

We devised a novel pneumatic-type dynamic traction and flexion (DTF-splint) splint [17] that pulls the articular surface and corrects flexural direction by combining PAM with a dynamic splint. This study investigated the flexion angle, total active motion (TAM) score, grasp strength, and pain (using a Visual Analog Scale [VAS] score) associated with wearing the splint by patients with MCP joint extension contractures; patients were randomly assigned to use either the DTF or conventional DFS-splint. Additionally, we examined the patients' clinical responses to the use of both splints

Methods

Study design and ethics

The trial protocol was approved by our hospital's ethics committee on human research. Written informed consent was obtained from all patients who agreed to participate in the research protocol was obtained prior to their enrollment in the study.

Patients

We evaluated 21 patients (52 fingers) with extension contractures of the MCP joints, less than six months after the contractures developed. A total of 13 men (29 fingers) and 8 women (23 fingers) were treated with either DFS or DTF-splints. The average age of the patients treated with DFS-splints was 42-years-old (range, 28−59-years old), and 49-years-old (range, 33−62-years-old) for those treated with DTF-splints. The contractures developed as a result of proximal phalanges fractures (5 patients, 6 fingers), metacarpal bone fractures (2 patients, 2 fingers), proximal phalanges and metacarpal bone fractures (4 patients, 8 fingers), extensor tendon injuries (3 patients, 8 fingers), distal radius fractures (4 patients, 16 fingers) and complex regional pain syndrome type II (3 patients 12 fingers). The subject fingers included 15 index, 7 middle fingers, 8 ring fingers and 22 little fingers. The affected fingers were treated with osteosynthesis (15 patients, 32 fingers) or conservatively (6 patients, 20 fingers) (Table 1).

The patients were directed to wear the assigned splint for their range of motion exercises. In all cases, the patients started wearing the splints when their elastic traction was 200 gf [4, 18−20]. The authors assisted patients to put it on every day for eight weeks. The splint had to be worn by the patients thrice in a day, in the morning, noon and night, for 30 minutes each. An occupational therapist checked each patient's traction power and appropriate wearing of the splint every 2 weeks.

Measurements

The subjects were randomly assigned to use either the GDS or DTF-splints. I carried out blind in Block Randomization. We evaluated the progress of the TAM scores (Total flexion angles – extension lag) and MCP joint flexion angles, every two weeks, over an eight-week period. TAM is used as one of the evaluation methods of the finger dysfunction. Further, we compared

Table 1. Characteristics of the patients with extension contractures of the MCP joints

	DTF		DFS	
	Patients (n)	Fingers (n)	Patients (n)	Fingers (n)
Sex				
Male	5	11	8	18
Female	4	14	4	9
total	9	25	12	27
Age (yrs)				
Male	46.4	NA	43.8	NA
Female	51.2	NA	46.3	NA
average	49 (33−62)	NA	42 (28−59)	NA
Disease				
Proximal phalanges and Metacarpal bone fracture	2	5	2	3
Extensor injure	1	4	2	4
Distal radius fracture	2	8	2	8
CRPS type1	1	4	2	8
total	9	25	12	27
Treatment type				
Osteosynthesis	6	13	9	19
Conservative	3	12	3	8
total	9	25	12	27
Subject				
Index	NA	7	NA	8
Middle	NA	3	NA	4
Ring	NA	4	NA	4
Little	NA	11	NA	11
total	NA	25	NA	27

the two groups for their ability to grasp and their experience with sharp pain (VAS score) when they started treatment with their assigned splint, and after 8 weeks of progress. The evaluator was an occupational therapist blinded to the purpose of the research. In addition, we carried out three times of evaluations. We calculated three times of means.

Structure and characteristic of the DFS and DTF-splints

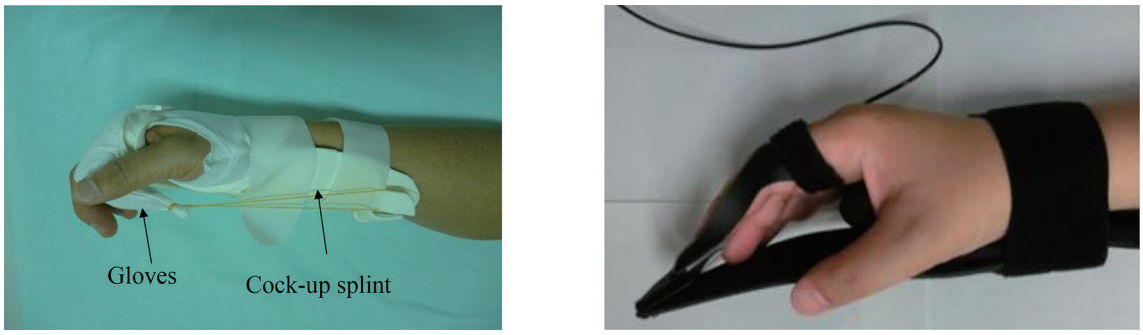
DFS-splint. The DFS-splint comprised a thermoplastic support (3 mm, no hole; OG Giken, Okayama, Japan), a Velcro strap and an elastic band (Figure 1A). The cock-up splint fixed the location of the wrist joint and metacarpal bones; the subject finger was positioned inside a glove that allowed the tip of the finger to be directly pulled, using the power of the elastic band, to flex the finger at the MCP joint.

DTF-splint. The DTF-splint comprised a wrist joint dorsiflexion instrument, a curved PAM and wrist joint-arthrodesis belt (Daiya Industrial, Okayama, Japan), a miniature gas cylinder (74 g, Nippon Tansan Gas, Tokyo, Japan), a Velcro strap and an elastic band (Figure 1B). A profile view of the splint (Figure 2) shows the characteristics of this splint that pulls the articular surface and corrects the flexural direction by applying a PAM to the dynamic splint; the splint permits the treatment of two or more fingers, simultaneously. The PAM used in this study is made of curved rubber (Figure 3A and 3B) and comprises a rubber tube covered with a bellows sleeve that only extends or contracts axially. By inhibiting the extension of one side, with the fiber reinforcement, the bending motion in the desired direction occurs by supplying compressed air to the rubber tube. As shown in Figure 3A, the curved tube is covered by an inner, non-contracting cloth and an outer, rubber cloth. The curved, rubber PAM bends when the rubber tube expands as result in the difference of the lengths of the rubber and cloth (outer and inner) covers. The bending motion was used to flex the joint, and the extension movement was used for joint traction (Figure 3B). The subject finger was wrapped to avoid any possibility of local ischemia.

Fig. 2. The PAM used in this study is the curved type pneumatic rubber artificial muscle.

Statistical methods

Statistical analyses were performed using the Kruskal-Wallis and Bonferroni methods for making within-group comparisons, and the Mann-Whitney



(a) The dynamic flexion splint (DFS splint)

(b) Pneumatic-Type Dynamic Traction and flexion splint (DTF splint)

Fig. 1. The dynamic splint used in this study.
A) Dynamic flexion splint; Couk-up splint fixed at the wrist joint and metacarpal bones. The flexion-type equip gloves on the subject's finger, pulls the tip of the finger directly in and causes flexion at the MP joint due to the rubber.
B) Pneumatic-Type Dynamic Traction and flexion splint: A characteristic motion of the artificial muscle is made possible such that extension and bending of the fingers takes place. The bending motion was used for flexion of the joint, and the movement of the extension was used for traction of the joint.

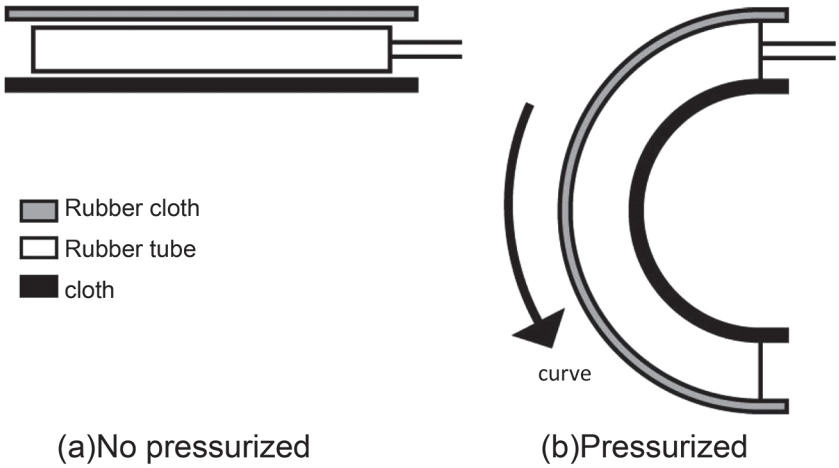


Fig. 3. Structure of the curved type pneumatic rubber artificial muscle.
A) Non pressurized rubber tube.
B) Pressurized curved rubber tube.

U-test was used to perform between-group comparisons. The significance of the differences between mean values was calculated. All statistical analyses were performed using the SPSS Base 11.0J statistics software (SPSS Japan, Tokyo, Japan); P-values < 0.05 were considered statistically significant.

Results

Table 2 shows the details of the effects of wearing both splint types over the 8-week treatment period.

MCP joint flexion angle

The pretreatment MCP joint flexion angles were 27.3 ± 10.8° and 23.3 ± 8.9° in the DFS and DTF-splint groups, respectively. In the DTF-splint group, the MCP joint flexion angles improved significantly more, over the 8-week treatment, than those in the DFS-splint group ($P < 0.05$, Table 2). Furthermore, the range of motion improvement was significantly improved in the group treated with the DTF-splint for 8 weeks, compared to those treated with the DFS-splint ($P < 0.01$, Table 2).

TAM scores

The pretreatment TAM scores for the DFS- and DTF-splint groups were 175.3 ± 19.8° and 171.5 ± 27.2°, respectively. Over the 8-week treatment period, the DTF-splint group showed significantly improved flexion angles compared with the DFS-splint group ($P < 0.05$). Furthermore, the TAM improvement was significantly greater for those wearing the DTF-splint than for those wearing the DFS-splint ($P < 0.01$).

Table 2. Evaluation results in relation to the use of dynamic flexion splint (DFS) and pneumatic-type dynamic traction and flexion (DTF).

	Evaluation	DFS	DTF	P value
Joint flexion (°)	pretreatment	27.3±10.8	23.3±8.9	0.65
	final	60.1±9.8	65.1±12.3	*0.04
	gain	32.8	41.8	†0.01
TAM	pretreatment	175.3±19.8	171.5±27.2	0.72
	final	207.9±10.9	218.7±12.3	*0.02
	gain	32.6	47.2	†0.01
Grasp (kg)	pretreatment	5.8±6.1	5.2±3.9	0.89
	final	25.3±9.8	22.6±10.7	0.61
	gain	19.5	17.4	0.08
VAS-score	pretreatment	2.2±1.0	2.5±0.5	0.54
	final	1.2±0.6	1.1±0.7	0.43
	gain	1	1.4	0.71

* P values < 0.05 were considered statistically significant.
† P values < 0.01 were considered statistically significant.

Grasp strength

The mean grasp strength of the patients wearing the DTF-splint was not significantly different from that for the patients wearing the DFS-splint, at the end of the treatment period. Hence, the improvements in the two groups were similar.

VAS-score

Similarly, there were no significant differences in VAS pain scores between the groups wearing the DFS and DTF-splints.

The 2-week rates of improvement for the patients wearing both types of splints

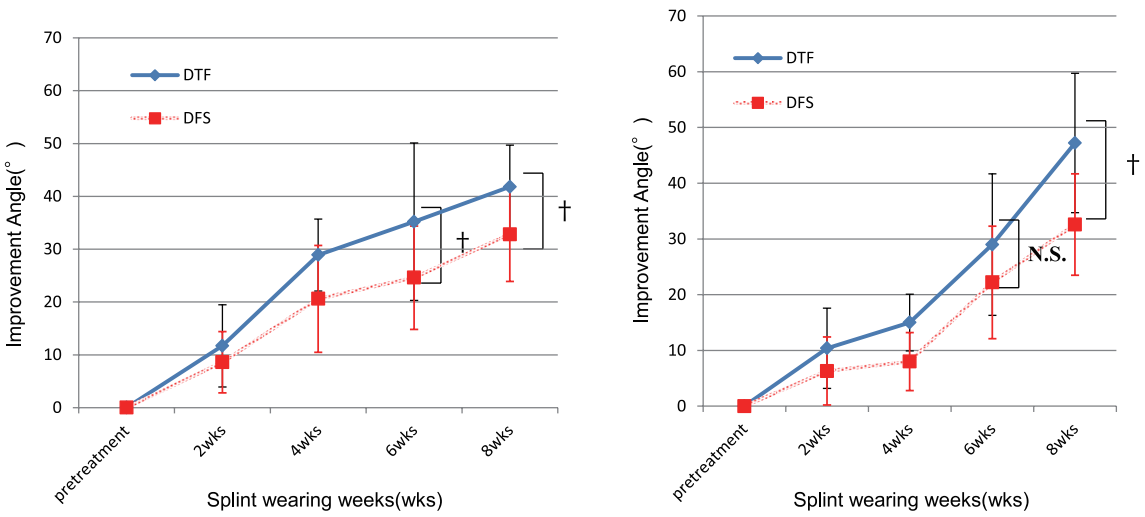


Fig. 4. The 2-week improvement rates in patients wearing DFS and DTF splint.
We dissected 21 patients 52 fingers. (A) was the MP joint flexion angle, (B) was the total Active Motion-score.
The significance level was set at $*p < 0.05$ $^{\dagger}p < 0.01$.

MCP joint flexion angle improvement angle (Figure 4A)

As shown in Figure 4A, for the first 4 weeks, there was no significant difference between the DTF and DFS-splint groups. However, patients wearing the DTF-splint improved significantly faster by weeks 6 and 8 than did the patients in the DFS-splint group ($P < 0.01$).

TAM score improvement angle (Figure 4B)

The TAM scores, over the first 6 weeks of treatment, were not significantly different between the two groups However; the DTF-splint group improved significantly more during the last two weeks of treatment than did the DFS-splint group ($P < 0.01$, Figure 4B).

Discussion

Generally, extension contractures are the most common contractures of the MCP joint. Maintaining maximum finger range of motion during the early treatment of these contractures is important to achieve optimal outcomes. Contracture of the MCP joint is a common clinical condition [17], but treatment is difficult and requires more time when the contracture is fully formed. This is the reason that the contractures should be treated as early as possible. There are several possible causes of joint contractures, including adhesions of the extensor tendons over the dorsum of the hand or of the extensor hood mechanism over the MCP joint; thickening of the dorsal MCP joint capsule; contracture of the collateral ligament; insufficient skin coverage or scarring of the skin over the dorsum of the hand, as in a burn; or a bony block within the joint [21, 22]. Of these, the most common cause of extension contractures of the MCP joint is shortening of the collateral ligament [11].

The dynamic splint is a well-accepted modality used for restoring joint motion to an injured hand. However, in extension contractures that involve a bent MCP joint, such treatment may not only be ineffective, but may also injure the articular cartilage causing greater damage. Therefore, thermotherapy is an effective treatment adjunct, prior to the use of a joint traction method [11]. This study assessed whether the DTF-splint is an effective device for treating MCP joint extension contractures. We used both the novel DTF-splint and the conventional DFS-splint to treat patients with extension contractures of the MCP joint. The results indicated that the DTF-splint yielded early recovery of both joint flexion angle and finger function. However, the changes in grasp strength and VAS scores were not significantly different between the DTF and DFS-splint treatments. Specifically, the improvement angle in the range of motion of the joint flexion angle was significantly improved at both 6 and 8 weeks of treatment, compared to joints treated using a DFS-splint. As a result, the TAM scores in joints treated using the DTF-splint were also significantly improved by week 8, compared to joints treated using the DFS-splint.

Generally, a PAM enables effective treatment to be delivered under conditions of relatively low pressure and reduced tension; PAM provided powered torque to the splint in the DTF-splint. Additionally, the utilization of PAM enables the use of a splint that is flexible, lightweight, easily maintained, and inexpensive. Recent studies have quantified the force-length, force-velocity,

force-activation, and bandwidth properties of artificial pneumatic muscles in detail [23−26]. The low compliance and high of the PAM is well suited for mimicking natural gait movements [24, 25] and, in the current orthosis, for providing a power-assisted glove [18].

According to our preliminary research, the joint space in the most palmar part of the MCP joint was increased by approximately 1.7 mm, using the DTF-splint compared to the joint, without orthotic treatment [18]. The DFS-splint works by adding tension to the joint, in the flexional direction, using elastic power to the fingertip. On the other hand, the DTF-splint allows extension and bending of the fingers. The bending motion was used to flex the joint, and extension was enabled using joint traction. Thus, the DTF-splint allows extension of the extensor tendon as well as the application of traction. The improved flexion angle of the whole finger, into the interphalangeal joint, was accomplished using the PAM along the full length of a finger. As a result, there was improvement in both the extension and flexion of the whole finger, including the interphalangeal joint.

The traction force of the DTF-splint extended the collateral ligaments of the MCP joints. This may indicate an improvement in the overall function of the finger as well as an improvement in the flexural angle, compared to fingers treated with a DFS-splint. However, as for the splints, a grip and a pain did not have a change. Furthermore, the effect in DTF-splint is not immediate, and it is actualized several weeks later. We regulated power of traction while being careful about sharp pain. Therefore, we think that stretch of tissue might take time. That is why there is not the DTF-splint immediate effect. However, it is the DTF-splint may be an effective tool for improving a patient's digital range of motion in comparison with DFS-splint several weeks later.

Study limitations

This study has a few limitations. First, each patient used the splint for only 8 weeks, rather than over a long period. Hence, we were unable to determine the period of treatment. Second, only patients who had been diagnosed with MCP joint contractures within 6 months of the start of the study were enrolled. Third, we did not evaluate the impact of the treatment on the activities of daily living. Finally, the study involved a limited number of patients. In future studies, we plan to increase number of patients and test the long-term effects of the splint and the usefulness of the splint for treating contractures diagnosed more than 6 months prior to the start of therapy.

Conclusion

Our results show that use of the novel DTF splint allows early improvements in the overall flexion of a finger and in the MCP joints flexural angle in patients with MCP joint extension contractures. Additionally, in this limited study, the DTF-splint appeared to be more effective than DFS-splints for treating patients with extension contractures of the MCP joint.

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■ORIGINAL ARTICLE

Effects of tasks involving different numbers of processes on working memory: Assessment by conducting cognitive function tests and using NIRS oxygen monitoring equipment

Katsumi Sugihara[1, 3], Mizuho Fujiwara[2], Hiroshi Furukawa[2]

[1] Faculty of Rehabilitation, Shijonawate Gakuen University
[2] Faculty of Rehabilitation, Kobe Gakuin University
[3] Graduate Student, Kobe Gakuin University Graduate School

Abstract: The present study examined the effects of tasks involving different numbers of processes on working memory (WM) by conducting cognitive function tests and using NIRS (near-infrared spectroscopy). The subjects were asked to perform two types of task involving varying numbers of processes. After the subjects performed both tasks involving one and multiple processes: drawing and the creation of a box, respectively, the oxygen hemoglobin concentration in the DLPFC was higher. However, there was no significant difference between the two tasks. The results of cognitive function tests following the production of boxes were also compared, and the PASAT 2 sec and SDMT scores were significantly higher. These results suggested that the efficient implementation of the task involving multiple processes generated an appropriate level of cognitive load required to promote the active functioning of WM and, as a result, the subjects achieved higher cognitive function test scores after completing the tasks.

Keywords: working memory, occupational therapy intervention, work-related practices, cognitive function

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Introduction

Baddeley and Hitch [1] define working memory (WM) as a system designed to maintain temporarily information required for sets of complex cognitive processes, such as language understanding, learning, and inference, and to manipulate it. The function of WM is required to facilitate smooth actions by a person, and it principally operates in the dorsolateral prefrontal cortex (DLPFC). The prefrontal region not only serves as a basis for high-level cognitive functions, including thinking and cognition, but is also responsible for goal-oriented actions, such as performing behaviors and memorizing plans [2].

In recent years, an increasing number of studies have suggested that exercise activates the DLPFC. According to Soya et al. [3], moderate or intense exercise for ten minutes activated the left DLPFC, and Taniguchi et al. [4] suggested that arm-reaching exercise activated the right DLPFC.

Other previous studies suggested that performing cognitive tasks improved cognitive functions and activated the prefrontal area. Komai et al. [5] asked patients with Alzheimer-type dementia to undergo training including visual and auditory tasks, and they received higher scores in cognitive function tests related to attentional function and WM following the training. Taniguchi et al. [4] conducted a test involving verbal WM tasks, and the prefrontal area of the subjects undergoing the tasks was activated, which suggested that WM functions are associated with the prefrontal area. According to the results of other previous studies, the implementation of meaningful tasks with respect to the values of individual participants [6] and antagonistic exercise performed by the elderly as a cognitive task effectively activated the prefrontal area [7]. Another previous study suggests that different tasks performed by examinees have varying influences on their cognitive functions. A study conducted by Nebes et al. [8] suggests that, al-

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Corresponding to: Katsumi Sugihara, Faculty of Rehabilitation, Shijonawate Gakuen University, 5-11-10, Hojo Daitou-city Osaka 574-0011, Japan
e-mail: sugihara@reha.shijonawate-gakuen.ac.jp
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though dysfunction cannot be noted when patients with mild Alzheimer-type dementia undergo simple attention tasks, patients tend to develop dysfunction while performing WM tasks and those that require the distribution and conversion of attention. These findings provided by previous studies suggest that performing exercise or cognitive tasks activates the cerebral blood flow in the prefrontal area and influences WM functions.

On the other hand, no previous studies focused on the number of processes involved in each task to examine the effects of its differences on WM. The system of WM actively processes information required to perform highly goal-oriented tasks while maintaining it [9]. Therefore, when a task involving multiple processes is performed, WM has a larger number of opportunities to maintain and operate information included in the processes actively. In other words, when a task involving a single process is performed, WM maintains and operates information fewer times. This led to the hypothesis that differences in the number of processes involved in each task may affect the activation of the DLPFC, which controls WM. The present study examined the effects of those differences on WM, using cognitive function tests and NIRS oxygen monitoring equipment (NIRO200NX, Hamamatsu Photonics). The subjects were asked to perform two tasks involving different numbers of processes.

Subjects and methods

1. Subjects

The subjects were ten college students, including four males and six females (mean age: 20.3 ± 0.5 years old). The subjects were asked to undergo the Edinburgh Handedness Inventory to confirm that their right arms are dominant.

2. Tasks and methods

In the present study, the following tasks were performed: "the creation of a box" involving four processes and "drawing using a mirror" consisting of one process.

The task of creating boxes using A4 craft paper has been introduced to many clinical settings in Japan since occupational therapists adopted it to assess problem-solving skills. The task can be easily introduced for the assessment of task implementation skills and cognitive functions as well as treatment in occupational therapy because tools and materials for the creation of boxes are readily available. The task also has meaning as treatment since the created boxes can be used in daily life.

In the experiment, the examiner presented a completed box to the subjects and explained the work procedure to them. The subjects were asked to create boxes while referring to a process chart including development views and a completed box, without receiving advice. The box, the length, width, and depth of which were 4, 4, and 3 cm, respectively, was created using craft paper. The tools used included pencils, rulers, scissors, and staplers. Four processes, or the following instructions, and development views were written on the process chart: (1) Draw a development view on craft paper, (2) Cut out the view with scissors, (3) Fold the paper into the shape of a box while ensuring that the margins of the paper for paste are facing in the proper direction, and (4) Overlap the margins and staple them.

In the drawing session, reflection drawing equipment (Takei Scientific Instruments Co., Ltd.), designed to assess the dexterity of the hands and learning skills, was used. There was only one process: the subjects drew a line between two star-shaped lines, using only a pencil. Although the numbers of processes and tools used were smaller, other conditions, including the provision of an explanation of the work procedure, presentation of the process chart, designation of tools, and responses to questions, were similar to those for the creation of boxes. Since the drawing task involved only one process: "Drawing a line with a pencil between two lines - an outline of a figure, reflected on a mirror", the subjects were required to refer to the process chart fewer times than for the task of creating a box.

3. Cognitive function tests

As cognitive function tests to assess WM, the Paced Auditory Serial Addition (PASAT) 1 and 2 second, Symbol Digit Modalities (SDMT), and Digit Span Tests (recital of numbers) were adopted. In the PASAT [10], participants listen to a CD and continue adding one-digit numbers that they have just been informed of in their head. The numbers are read out at an interval of one or two seconds. In the SDMT [10], participants write a number that corresponds to each of nine symbols according to a rule. The recital of numbers [10] assesses the auditory memory span, and there are two types: participants recite the numbers that have been read out by an examiner in the normal or reverse order (normal- and reverse-order recitals).

4. Measuring equipment

NIRS (near-infrared spectroscopy) is a non-invasive brain-function diagnostic imaging technique used to measure cerebral activities. In rehabilitation and other fields, oxygen hemoglobin (Oxy-Hb) concentrations and their changes, which depend on neural activity, have been measured [11]. The prefrontal area is considered to be a representative cortex in charge of performing WM tasks. In recent years, an increasing number of studies

Fig. 1. Dipping of probes.

have been conducted to assess the functions of the frontal lobe using NIRS [2]. NIRS was adopted to analyze the activation of the DLPFC - the targeted measurement site. A pair of one-channel probes (for left and right) were attached 5 cm from the C3 and C4 points in the sagittal direction according to the international 10−20 method, based on the method developed by George et al. [12]. Time-series NIRS data within a specific period of time are related to each other, and cannot be regarded as independent. Therefore, a block design was adopted, in which the same task followed by a rest was repeated, to analyze statistically changes in the Oxy-Hb concentration during the tasks [13].

Furthermore, there were also spontaneous periodic variations in NIRS measurements other than those attributed to the activation of the brain while performing the tasks. In addition, the blood also flows in the tissues of the surface layer of the head other than the brain parenchyma, so NIRS measurements are also influenced by the dynamics of the blood flow. The above-mentioned results suggest that it is necessary to control the movement and postures of the subjects appropriately and implement baseline correction based on measurements at rest in order to prevent artifacts from interfering with NIRS measurements [14]. Therefore, prior to attaching the probes to the bodies of the subjects, they were asked to assume a specific sitting position so that their body movements could be controlled and their hands could be observed while performing the tasks. They were also instructed not to close or open their eyes too widely during measurement. After receiving these instructions, the subjects underwent measurement and performed the tasks when the waveform had become stable.

5. Experimental procedures

The experimental procedures are presented in Figs. 2 and 3. The experiment was conducted for each individual subject in an experimental room that lacked external stimuli. The following research procedure was implemented: (1) Cognitive functional tests (PASAT 1 sec and 2 sec, SDMT, and recitals in the normal and reverse orders) had been conducted before the subjects performed the tasks. (2) NIRS probes were attached to the subjects and, after confirming that the waveforms were consistent, measurement was conducted while the subjects performed the tasks. (3) The subjects performed a 180-second task four times at rest intervals of 30 seconds. While resting, the subjects were asked to assume the same posture as that when they performed the task, and gaze at the "+" mark on the screen of a PC. (4) When the subjects had completed the task, the probes were detached from them. (5) Cognitive function tests (PASAT 1 sec and 2 sec, SDMT, and recitals in the normal and reverse orders) were conducted for the subjects who had completed the task.

The processes and tools were prescribed so that the subjects would not become confused when performing the task. The process of the task and tools were designated to help the subjects perform it efficiently and facilitate the active maintenance and manipulation of

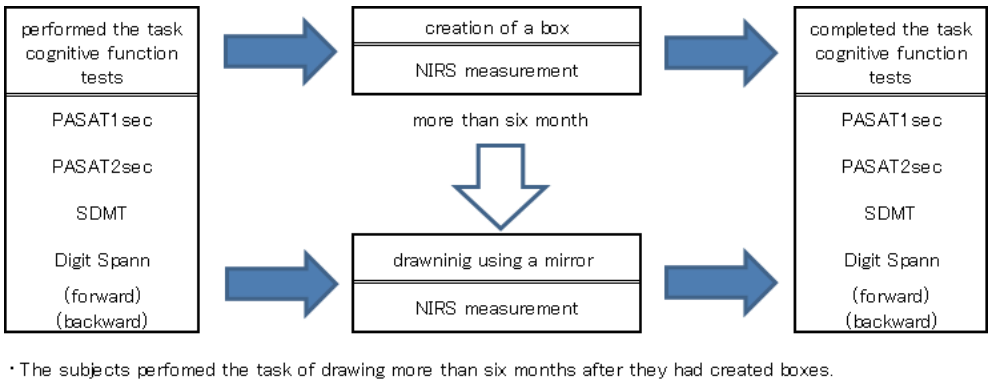

Fig. 2. Experiment procedures.

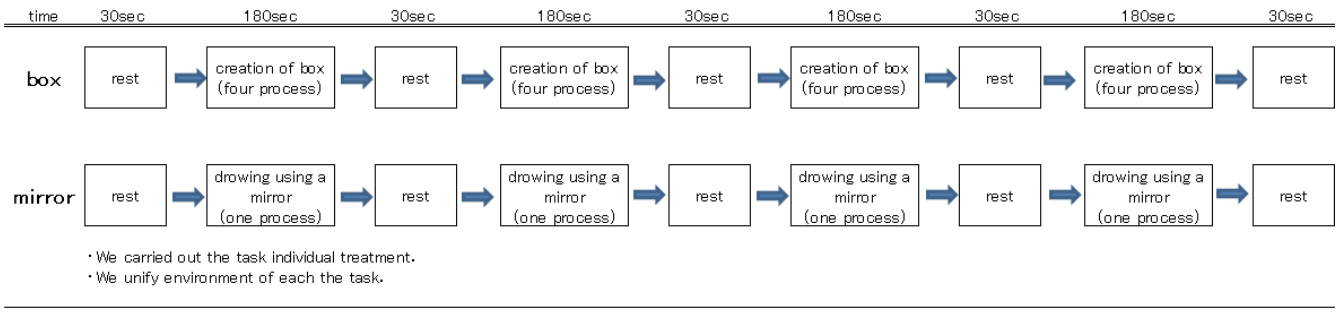

Fig. 3. Instruction procedures.

information - functions of WM. The examiner did not provide the subjects with advice on the method for performing the task efficiently. The subjects could improve the efficiency of performing the task - creation of four boxes, by implementing the following methods: omit drawing folding lines when "drawing a development view on craft paper", and reducing the frequencies of referring to the development view to confirm the dimensions and the process chart. Although the subjects were supposed to follow the order of the processes when performing the task, they were allowed to improve the work efficiency by modifying the procedure, which was expected to affect WM.

The subjects performed the task of drawing according to the same procedure more than six months after they had created boxes. This was because participation in cognitive function tests often enhances learning effects, and the experiments involving college students as the subjects were conducted during the periods of their summer and winter vacations. The subjects were in the same school year in the same college and involved in similar activities in their school lives. There was no significant difference in their mean age when they performed the tasks (20.3 ± 0.5 and 21.1 ± 0.3 years old at the time of the production of boxes and drawing, respectively). The present study was conducted with the approval of the ethics committee of Kobe Gakuin University. The subjects received written and verbal explanations of the purpose of the study and its method, and consented to participate in it (Approval number: HEB120706-1).

Analysis methods

1. Analysis of the activation of the DLPFC

In NIRS data analysis, conducting averaging can isolate stimulus-dependent responses. Specifically, adding and averaging are performed to correspond to the intervals of similar stimuli applied multiple times to eliminate the waveforms of background activities, which fluctuate independently of the timing of the stimuli applied, and identify only stimulus-dependent responses [11]. In the present study, the body movements and postures were appropriately controlled to exclude data mixed with artifacts. The means of Oxy-Hb concentrations during 170 of the 180 seconds required to perform each task, excluding the first 10 seconds, were calculated as the Oxy-Hb activation values, and their baseline correction was conducted. The mean of Oxy-Hb concentrations measured during the first to third resting periods was calculated as the resting-state (baseline) value. The procedure for measurement was as follows: Immediately prior to the start of measurement, the subjects were instructed to look at a picture on a wall in front of them, and performed the tasks when the waveform had become stable.

The Wilcoxon signed-rank test was conducted to compare the Oxy-Hb activation and resting-state values between the two tasks. The resting-state value was subtracted from the Oxy-Hb activation value for comparison, and the relative activation values and baseline levels were compared between the tasks, using the Mann-Whitney U test. The significance level was set to less than 5%.

2. Analysis of cognitive function test scores

The subjects performed the task of drawing more than six months after they had created boxes because participation in cognitive function tests often enhances their learning effects. The cognitive function test scores before the tasks were performed were defined as the baseline values. The paired t-test was conducted to compare the scores received prior to and following the cognitive function tests between the two tasks. The baselines were compared between the two tasks, and differences between the cognitive function test scores received before and after the tasks had been performed were calculated and compared between the tasks, using Welch's test. The significance level was less than 5%.

Results

1. Oxy-Hb concentrations and baseline levels as the results of cognitive function tests

Table 1 shows that there were no significant differences in the Oxy-Hb concentration in the DLPFC and cognitive function test baselines for the tasks of creating boxes and drawing between the two tasks.

2. Oxy-Hb concentrations

(1) Resting-state and activation values (Oxy-Hb concentrations)

Table 2 shows Oxy-Hb concentrations (resting-state and activation values) measured during the creation of boxes and drawing.

1) Creation of boxes

Significant activation was noted in the right DLPFC (resting-state value in the right DLPFC: 1.0 ± 1.0 μmol/L, activation value in the right DLPFC: 1.7 ± 1.5 μmol/L, $p < 0.05$). There was no significant difference in the value in the left DLPFC (resting-state value in the left DLPFC: 0.7 ± 1.0 μmol/L, activation value in the right DLPFC: 1.3 ± 1.7 μmol/L).

2) Drawing

Significant activation was noted in both areas of the DLPFC (resting-state value in the left DLPFC: 0.2 ± 1.4 μmol/L, activation value in the left DLPFC: 0.9 ± 1.5 μmol/L, $p<0.01$) (resting-state value in the right DLPFC: 1.5 ± 0.9 μmol/L, activation value in the right DLPFC: 2.6 ± 1.1 μmol/L, $p < 0.01$).

Table 2. Oxy-Hb concentrations (resting-state and activation values) measured during the creation of boxes and drawing.

DLPFC			Resting-state value (mmol/L)		Activation value (mmol/L)		P value
			Mean	SD	Mean	SD	
Box	Left	Oxy-Hb	0.7	1.0	1.3	1.7	0.2
Box	Right	Oxy-Hb	1.0	1.0	1.7	1.5	0.04*
Mirror	Left	Oxy-Hb	0.2	1.4	0.9	1.5	0.0093**
Mirror	Right	Oxy-Hb	1.5	0.9	2.6	1.1	0.0051**

**$p < 0.01$ *$p < 0.05$ n = 10

• The subjects performed the task of drawing more than six months after they had created boxes.

3) Comparison of relative Oxy-Hb activation values between the tasks

Relative Oxy-Hb activation values were compared between the tasks. There were no significant differences in the values for both sides between the two tasks (creation of a box in the left DLPFC: 0.6 ± 1.1 μmol/L, drawing in the left DLPFC: 0.6 ± 0.6 μmol/L) (creation of a box in the right DLPFC: 0.7 ± 0.9 μmol/L, drawing in the right DLPFC: 1.1 ± 0.8 μmol/L). Figs. 4 (creation of boxes) and 5 (drawing) show the mean waveforms for the two tasks.

Table 1. Oxy-Hb concentrations and baseline levels as the results of cognitive function tests.

DLPFC			The creation of a box		Drawing using a mirror		U value	P value
			Mean	SD	Mean	SD		
Left	Oxy-Hb	(mmol/L)	0.3	0.7	0.6	1.4	0.2	0.9
Right	Oxy-Hb	(mmol/L)	0.1	0.7	0.1	0.4	0.1	0.9
Cognitive function tests			The creation of a box		Drawing using a mirror			P value
			Mean	SD	Mean	SD		
PASAT1 second		(points)	62.4	18.3	67.1	11.7		0.5
PASAT2 second		(points)	87.8	9.6	94.9	5.2		0.1
SDMT		(points)	67.8	9.1	65.2	16.1		0.7
Forward		(figure)	7.1	0.9	7.0	1.1		0.8
Backward		(figure)	5.2	0.6	4.6	0.8		0.2

n = 10

• The subjects performed the task of drawing more than six months after they had created boxes.
• Oxy-Hb: oxygen hemoglobin concentrations
• In the PASAT, participants listen to a CD and continue adding one-digit numbers that they have just been informed of in their head. The numbers are read out at an interval of one or two seconds.
• In the SDMT, participants write a number that corresponds to each of nine symbols according to a rule.
• The recital of numbers assesses the auditory memory span, and there are two types: participants recite the numbers that have been read out by an examiner in the normal or reverse order.

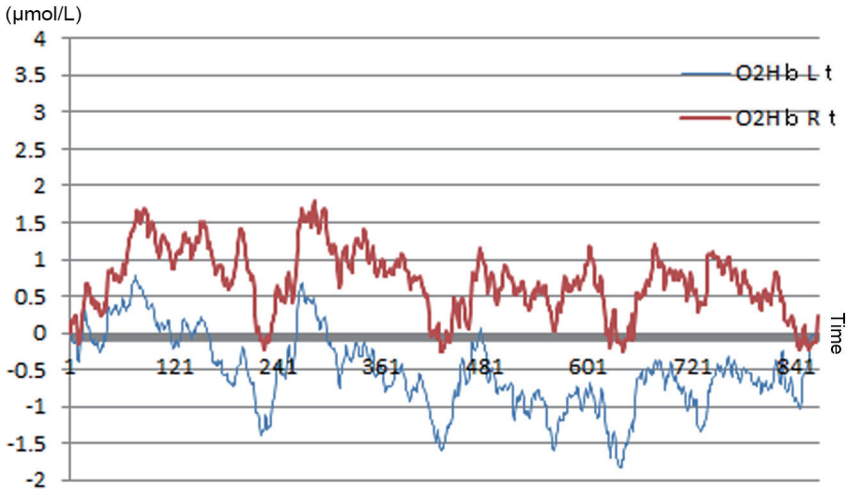

Fig. 4. Wave form of the creation of a box.
• Average waveform of relative value in the creation of a box.
• Bold line is the right side, and a thin line is a left side.

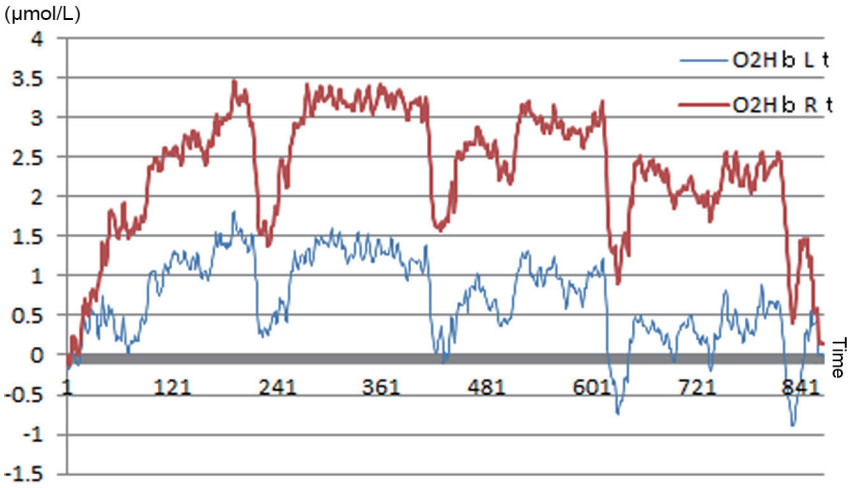

Fig. 5. Wave form of droawing using a mirror.
• Average waveform of relative value in droawing using a mirror.
• Bold line is the right side, and a thin line is a left side.

3. Results of cognitive function tests

(1) Comparison of cognitive function test scores before and after the tasks were performed

Table 3 shows the results of the comparison of cognitive function test scores before and after the creation of boxes and drawing were performed.

1) Creation of boxes

There were significant increases in the mean scores for the PASAT 2 sec (prior to the task: 87.8 ± 9.6 points, following the task: 93.9 ± 4.9 points, $p < 0.05$) and SDMT (prior to the task: 67.8 ± 9.1 points, following the task: 77.2 ± 11.9 points, $p < 0.01$). There were no significant differences in the scores for the PASAT 1 sec (prior to the task: 62.4 ± 18.3 points, following the task: 67.9 ± 13.8 points), normal-order citation (prior to the task: 7.1 ± 0.9 points, following the task: 7.4 ± 1.1 points), and reverse-order citation (prior to the task: 5.2 ± 0.6 points, following the task: 5.3 ± 1.1 points).

2) Drawing

There was a significant increase in the PASAT 1 sec (prior to the task: 67.1 ± 11.7 points, following the task: 74.6 ± 10.9 points, $p < 0.01$). There were no significant differences in the scores for the PASAT 2 sec (prior to the task: 94.9 ± 5.2 points, following the task: 94.9 ± 7.6 points), SDMT (prior to the task: 65.2 ± 16.1 points, following the task: 69.3 ± 16.8 points), normal-order citation (prior to the task: 7.0 ± 1.1 points, following the task: 7.2 ± 1.0 points), and reverse-order citation (prior

Table 3. The results of the comparison of cognitive function test scores before and after the creation of boxes and drawing were performed.

The creation of a box		Prior to the task		Following the task		P value
		Mean	SD	Mean	SD	
PASAT1 second	(points)	62.4	18.3	67.9	13.8	0.17
PASAT2 second	(points)	87.8	9.6	93.9	4.9	0.02*
SDMT	(points)	67.8	9.1	77.2	11.9	0.003**
Forward	(figure)	7.1	0.9	7.4	1.1	0.08
Backward	(figure)	5.2	0.6	5.3	1.1	0.59
Drawing using a mirror		**Prior to the task**		**Following the task**		**P value**
		Mean	SD	Mean	SD	
PASAT1 second	(points)	67.1	11.7	74.6	10.9	0.004**
PASAT2 second	(points)	94.9	5.2	94.9	7.6	0.99
SDMT	(points)	65.2	16.1	69.3	16.8	0.13
Forward	(figure)	7.0	1.1	7.2	1.0	0.34
Backward	(figure)	4.6	0.8	4.9	0.5	0.27

**$p < 0.01$ *$p < 0.05$ n = 10

• The subjects performed the task of drawing more than six months after they had created boxes.

to the task: 4.6 ± 0.8 points, following the task: 4.9 ± 0.5 points).

(2) Comparison of differences in cognitive function test scores prior to and following the tasks

Differences in test scores before and after the tasks of creating boxes and drawing had been performed (value following the task - value prior to it) were compared. There was a significant increase in the PASAT sec 2 score following the creation of boxes (creation of a box: 6.2 ± 6.9 points, drawing: −0.01 ± −4.7 points, $p < 0.05$). There were no significant differences in scores for cognitive function tests other than the PASAT 1 sec (creation of a box: 5.4 ± 11.3 points, drawing: 7.5 ± 6.1 points), SDMT (creation of a box: 9.3 ± 7.4 points, drawing: 4.1 ± 7.8 points), normal-order citation (creation of a box: 0.3 ± 0.4 points, drawing: 0.2 ± 0.6 points), and reverse-order citation (creation of a box: 0.1 ± 0.6 points, drawing: 0.3 ± 0.8 points).

Discussion

In the present study, the subjects performed two tasks involving different numbers of processes, and the effects of their differences on WM were assessed by conducting cognitive function tests and NIRS, and based on the cerebral blood flow in the DLPFC and other test results. Prior to conducting analyses, the following point was confirmed: there were no significant differences in the Oxy-Hb concentrations in the DLPFC and baseline levels determined by the cognitive function tests between the two tasks.

The study results were as follows: there were no significant differences in the Oxy-Hb concentration in the DLPFC and baseline levels determined by the cognitive function tests after both tasks were performed. Although the Oxy-Hb concentration in the DLPFC was significantly higher after both tasks were performed, no significant difference was noted between the two tasks. Cognitive function test scores were significantly higher following the creation of a box, which involved multiple processes. There were significant increases in the mean scores for two cognitive function tests after the subjects performed the task of creating a box. In the comparison of cognitive function test scores between the two tasks, the mean score for the PASAT 2 sec following the creation of a box was significantly higher.

Oxy-Hb concentrations were significantly higher in the right area of the DLPFC after the subjects created a box, and in both left and right areas after they performed the task of drawing. An increase in the Oxy-Hb concentration in the right prefrontal area is related to the positional relationship between a person and an object. On the other hand, an increase in the Oxy-Hb concentration in the left prefrontal area is related to the eye movement to gaze at an object and the function of WM to process spatial information [15, 16]. There was a significant increase in the Oxy-Hb concentration in the right prefrontal area following the creation of a box, presumably because WM continues using visual images when a subject creates a box. The task of drawing was performed using a mirror. Complex motor learning including the skillful use of a pencil by the subjects presumably involved the processing of information obtained from the eye movement and other visual infor-

mation. These results suggest that the task of drawing significantly increased the Oxy-Hb concentrations in both left and right prefrontal areas. However, there was no significant difference in the relative Oxy-Hb activation value between the two tasks. This suggests that the effects of tasks involving different numbers of processes on WM cannot be explained solely by an increase in the Oxy-Hb concentration in the DLPFC.

Regarding the cognitive function tests following the completion of the tasks, the mean correct answer rates in the PASAT 2 sec and SDMT were significantly higher after the subjects had created boxes. On the other hand, only the correct answer rate in the PASAT 1 sec was significantly higher after the task of drawing was performed. In the comparison of the two tasks, the mean correct answer rate in the PASAT 2 sec was significantly higher after the task of creating a box involving multiple processes had been performed, compared with the task of drawing. According to Callicott et al. [17], WM in the prefrontal area is less activated when the cognitive load is excessively large or small, and more activated when the appropriate amount of cognitive load is applied. The processes of the tasks and tools were prescribed to help the subjects concentrate on the tasks and to facilitate the active maintenance and manipulation of information - functions of WM.

The number of processes involved in the creation of a box is larger than for the task of drawing, which means that there are more opportunities for improving the work efficiency. When the work efficiency was high, the appropriate amount of cognitive load was applied and WM was activated - there were significant changes in the cognitive function test scores following the completion of the tasks.

Levine et al. [18] conducted research on the effects of goal management training (GMT), and suggested that GMT, in which trainees learn about planning and goal accomplishment, is a method for improving frontal lobe dysfunction. In this method, the planning of a final goal involves the setting of multiple sub-goals, and the final goal is accomplished by conducting goal management, or the accomplishments of all sub-goals. Since WM functions the most effectively when people are goal-oriented, undergoing GMT is expected to improve the functions of WM. When a box is created, or to reach the final goal, four processes as sub-goals are accomplished one by one and, as a result, WM is rewritten more frequently than when the task of drawing is performed. The goal of the task of drawing is to draw a line between two lines, which serve as an outline of a figure. When a line is drawn - a task involving only one process, sub-goals are accomplished fewer times than when a box is created, and WM is also rewritten fewer times. WM is used less frequently during drawing than when a box is created, presumably due to a smaller number of processes required for the task of drawing. Kingberg et al. [19] suggest that, when patients undergo WM tasks as part of training, changing the difficulty level for each patient will improve the effect. The results of the present study suggest that, as the capacity of WM varies from person to person, WM can be effectively activated by changing the number of processes involved in tasks according to the WM capacity.

Although the present study focused on the number of processes involved in each task to examine the effects of its differences on WM, it is also necessary to discuss learning methods for performing tasks. When the subjects draw a line between two star-shaped lines reflected on a mirror, they make mistakes until they learn to use the pencil with dexterity. In other words, they make many mistakes to master complex motor learning and become able to draw properly. Since it is difficult to correct false responses caused by mistakes as one of the characteristics of the task, Watamori et al. [20] suggest that a learning method that prevents mistakes (errorless learning) effectively helps people memorize new things. In principle, the task of creating boxes is based on errorless learning because the process chart is referred to and it is not difficult to imagine a completed box. Both errorless learning and GMT are considered to be effective in the creation of a box involving four processes.

In the present study, the oxygen hemoglobin (Oxy-Hb) concentration in the DLPFC following the completion of the task was significantly higher, and cognitive function test scores were influenced by the creation of a box - a task involving multiple processes. However, there was no significant difference in the relative Oxy-Hb activation value in the DLPFC between the two tasks. This suggests that, although the scores in the cognitive function test (designed to assess the functions of WM) following the production of boxes were higher than the test scores after the completion of the task of drawing, the effects of a difference in the number of processes on the functions of WM could not be adequately explained.

As a future task, it is necessary to measure the capacity of the WM of subjects, and calculate the appropriate amount of cognitive load applied when performing a task. The spatial resolution of NIRS is low and it can only determine values relative to Oxy-Hb baseline values and their changes, so it will be necessary to interpret values by combining actual measurements with baseline values obtained using PET and other methods, as a future challenge.

Conclusion

The present study examined the effects of two tasks involving different numbers of processes on WM by assessing the cerebral blood flow in the DLPFC and conducting cognitive function tests to assess the functions of working memory (WM). Although the oxygen hemoglobin (Oxy-Hb) concentration in the DLPFC was significantly higher after the subjects had performed both tasks, there was no significant difference between the two tasks. The results of cognitive function tests following the production of boxes were also compared, and the mean PASAT 2 sec and SDMT scores were significantly higher. Cognitive function test scores after the two different tasks had been performed were compared, and the PASAT 2 sec score following the task of creating a box was significantly higher than the score after drawing. The processes of the tasks and tools were prescribed to help the subjects perform the tasks efficiently and facilitate the active maintenance and manipulation of information - functions of WM. The task of creating a box, which involves a larger number of processes, provided the subjects with an opportunity for performing it more freely and efficiently than the task of drawing. The results suggested that the efficient implementation of the task involving multiple processes generated an appropriate level of cognitive load required to promote the active functioning of WM and, as a result, the subjects achieved higher cognitive function test scores after completing the tasks. The scores in the cognitive function test (designed to assess the functions of WM) following the production of boxes were higher than the test scores after the completion of the task of drawing, presumably because the production of a box involved multiple steps, in which the subjects were able to improve their work efficiency. However, since there was no significant difference in the relative Oxy-Hb activation value between the two tasks, the effects of a difference in the number of processes have not yet been completely clarified.

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