Reading Aloud and Arithmetic Calculation Improve Frontal Function of People With Dementia

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Background. Recent findings of neuroimaging studies indicate that reading aloud and arithmetic calculation activate bilateral dorsolateral prefrontal cortex of humans. The purpose of this study was to measure the effect of reading aloud and arithmetic calculation, by elderly people who were clinically diagnosed with dementia Alzheimer type, on their brain functions and activities of daily living.

Methods. Sixteen experimental and 16 age- and Mini-Mental State Examination score-matched control subjects participated. The participants in the experimental group were asked to perform a training program using learning tasks in reading and arithmetic for 2–6 days a week. The function of the frontal cortex of the subjects was assessed by FAB at bedside (Frontal Assessment Battery).

Results. After 6 months of training, the FAB score of the experimental group showed a statistically significant improvement. The FAB score of the control group decreased slightly over the 6-month period, and the difference between the scores of the experimental and control groups was statistically significant. We also observed the restoration of communication and independence in the experimental group.

Conclusion. Our results indicate that learning tasks of reading aloud and arithmetic calculation can be used for cognitive rehabilitation of dementia patients.

Recenrtly, the importance of cognitive rehabilitation for patients with dementia has been argued (1). The aims of cognitive rehabilitation for patients with dementia include optimizing functioning and well-being, minimizing the risk of excess disability, and preventing the development of a malignant social psychology within the patient’s family and social environment (2). Because memory impairment is a common attribute of any dementia subtypes, most of the intervention programs for dementia care focus on memory trainings (3–6).

In this study, we propose a new intervention program, the concept of which is derived from the knowledge of both brain science and clinical studies. Memory impairment and cognitive disturbances, such as aphasia, apraxia and agnosia, and disturbance of executive function, are the main cognitive deficits in dementia, and the association cortices, particularly the dorsolateral prefrontal cortex, are involved in these cognitive functions (7,8). The decrease in regional cerebral blood flow (rCBF) in the frontal, parietal, and temporal association cortices is commonly the case for dementia (9–11). Therefore, cognitive impairments in dementia patients may well result from dysfunction in those association cortices.

In human brain-mapping studies, brain areas showing increases in rCBF and metabolism in relation to performance of cognitive tasks have usually been reported (12). Therefore, we can identify specific cognitive tasks which increase rCBF and metabolism of these association cortices, particularly the dorsolateral prefrontal cortex, from those in previous brain-imaging studies. In this study, we hypothesized that activation of the association cortices by cognitive tasks may well improve rCBF and metabolism of these cortices, which lead to improve the function of these cortices.

To choose effective cognitive tasks for activation of the association cortices, we reviewed previous neuroimaging studies published elsewhere and/or those by our laboratory. In this process, we selected brain-activation paradigms that satisfy the following two criteria: a) the paradigms must activate the dorsolateral prefrontal cortex, as well as the parietal and temporal association cortices of the bilateral hemispheres compared with the resting state, and b) the paradigms must be very simple, so that people with senile dementia can follow and perform them. Finally, we identified two tasks: a) reading sentences or words aloud (13–16) and b) performing simple arithmetic operations (17–22), both of which met our above-mentioned criteria.

Therefore, we prepared two tasks in arithmetic and Japanese language, which were systematized basic problems in reading and arithmetic, for the training program. The theoretical flaw of our hypothesis is that it is not clear whether activation of brain networks involved in reading and calculations can improve functions of brain network(s) involved in other cognitive processes. To test our hypothesis...
and to overcome this problem, we measured the effect of continuous learning by elderly people with dementia on their brain functions and activities of daily living. In this study, we focused mainly on the function of the frontal cortex. The limitation of this study is that we could not determine the role of social, emotional, and cognitive factors in the training effect.

METHODS

Subjects

Sixteen individuals in the experimental group and 16 in the control group were recruited from a nursing home for the elderly, called Eiju-no-Sato, in Fukuoka, Japan. The subjects were randomly assigned to these two groups. Written informed consent was obtained from each individual using forms approved by the Tohoku University and the Declaration of Helsinki (1975). Clinical diagnostic evaluation by neurologists and an X-ray computed tomography examination of the brain were performed on each participant. In this study, none of the participants had abnormalities such as tumors, cerebral bleeding, cerebral infarction, or pathological brain atrophy, on X-ray computed tomography examination. All of the individuals in both groups had a clinical diagnosis of dementia Alzheimer type (DAT) that met the criteria of the American Psychiatric Association’s Diagnostic and Statistical Manual of Mental Disorders, 4th edition (DSM-IV). The participants in the learning group were asked to perform a training program using learning tasks 2–6 days a week at learning centers in Eiju-no-Sato. To estimate the change in the cognitive ability of the participants, Mini-Mental State Examination (MMSE) (23) and Frontal Assessment Battery at bedside (FAB) (24) were measured in each participant of each group. In the learning group, the neuropsychological characteristics were measured prior to the start of the training program (baseline) and 6 month after the training program had taken place (follow up). In the control group, the same characteristics were measured at the same time as in the learning group. The baseline clinical and neuropsychological characteristics of the learning and control participants are summarized in Table 1. In addition, ability for verbal communication and independence was estimated in both groups by two individual items of scales for mental state and daily living activities for the elderly, named the NM scale (25). Neither assessment score showed a statistically significant difference between the two groups (independent samples t test).

Except for the training program, both groups of participants had the same nursing care programs at the same place.

Learning Tasks

The materials for the training program were two tasks in arithmetic and Japanese language, which were systematized basic problems in reading and arithmetic. We prepared a wide range of materials, which were used for everyday learning for 4-year-old children to fourth grade elementary school students (that is, 10-year-olds). The problems were printed on both sides of A4-size paper. As for the arithmetic problems, the lowest level was counting practice, and the highest level was three-digit division. As for the Japanese language problems, the lowest level was to read and write single syllables, and the highest level was to read aloud fairy tales. Prior to the training program, the appropriate degree of difficulty and workload for each participant were assessed by a diagnostic test, so that he or she could continue to perform the learning tasks with ease.

The participants came to the learning center either on summons by the staff, or on their own initiative every day from Monday to Saturday. They would complete two to five sheets of each task prepared for each individual for that day, and their work would be assessed by the staff. The mistakes were corrected by the participants. If they could not solve a problem by themselves, the staff members stationed between desks provided sufficient advice for them to be able to solve it. The study period ended when the participants completed each of the problems correctly. The daily learning time for the two tasks was approximately 20 minutes.

Statistical Analyses

The neuropsychological characteristics of both groups were compared using an independent sample t test at baseline and at follow-up. A further analysis comparing baseline and follow-up scores separately for the learning and control groups was performed by paired t test. Statistical significance was set at \( p < .05 \) for all the comparisons.

RESULTS

Neuropsychological Characteristics

All the participants in the learning group continued the program for more than 6 months. The mean (SD) of the training days was 19.2 (4.6) days per month.

The scores of the neuropsychological characteristics at baseline and follow-up are summarized in Figure 1. In the learning group, the FAB score showed a statistically significant (\( p < .05 \)) increase after the training had taken place. However, the MMSE score did not show any significant changes. In the control group, the MMSE score showed a statistically significant (\( p < .05 \)) decrease at follow-up compared with baseline. Nevertheless, the FAB score did not show any significant changes. At follow-up, the MMSE and FAB scores for the learning group were statistically significantly (\( p < .05 \)) higher than those for the control group. There was no relationship between the magnitude of change in the scores of the neuropsychological
The scores of the individual items of the FAB at baseline and follow-up are summarized in Table 2. At follow-up, the score for similarities (conceptualization) was significantly (p < .05) higher in the learning group compared with the control group. In the control group, the score for motor series (programming) showed a statistically significant (p < .05) decrease at follow-up compared with baseline. In the learning group, the score for similarities (conceptualization) showed a statistically significant (p < .01) increase at follow-up compared with baseline. There was no relationship between the magnitude of change in the scores of the individual items of the FAB and the number of training sessions that the learning group participants attended.

The scores of the individual items of the NM scale at baseline and follow-up are summarized in Table 3. In the learning group, the score for independence showed a statistically significant (p < .05) increase at follow-up compared with baseline. Although score for verbal communication showed an increase at follow-up compared with baseline, it did not reach a statistically significant level (p = .1). In the control group, the score for verbal communication showed a subthreshold decrease at the p = .1 level at follow-up compared with baseline.

**Examples of the Case Patients**

**Case 1.**—A 75-year-old man had baseline FAB and MMSE scores of 3 and 13, respectively. After the 6-month training period, his FAB and MMSE scores increased to 10 and 15, respectively. He showed reactivation of his communicative ability during the course of training. Before the start of the training, he could only speak a few words, and remained motionless in the same place, wearing an anxious expression. After the learning period, his number of spoken words increased, his voice became clearer, and he initiated conversation on his own. Moreover, before the learning period he had to be reminded by the staff about bowel movements, but 3 months after the learning period, he was able to go to the toilet by himself.

**Case 2.**—A 77-year-old woman had baseline FAB and MMSE scores of 5 and 7, respectively. She also showed reactivation of her communicative ability during the course of training. Before the learning period she almost did not converse at all. She began to speak simple words, and after 6 months, she could hold a simple conversation, and began to return smiles to the staff in corridors. In particular, right

Table 2. Mean Subscores on the Frontal Assessment Battery

<table>
<thead>
<tr>
<th>Item</th>
<th>Control Group</th>
<th>Learning Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>Follow-Up</td>
</tr>
<tr>
<td>Similarities (conceptualization)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lexical fluency (mental flexibility)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motor series (programming)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conflicting instructions</td>
<td></td>
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<tr>
<td>Go-No Go (inhibitory control)</td>
<td></td>
<td></td>
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<tr>
<td>Prehension behavior (environmental autonomy)</td>
<td></td>
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</tr>
</tbody>
</table>

Notes: Numbers in parentheses are standard deviations.

* ** indicate statistically significant changes between baseline and follow-up states (p < .05 and p < .01, respectively, by paired t test).

Table 3. Mean Subscores for Two Items on the N Mental State Scale for the Aged

<table>
<thead>
<tr>
<th>Item</th>
<th>Control Group</th>
<th>Learning Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>Follow-up</td>
</tr>
<tr>
<td>Independence</td>
<td>5.5 (2.5)</td>
<td>5.5 (1.9)</td>
</tr>
<tr>
<td>Verbal communication</td>
<td>8.0 (2.1)</td>
<td>7.4 (1.9)</td>
</tr>
</tbody>
</table>

Notes: Number in parentheses are standard deviations.

* Indicates statistically significant changes between baseline and follow-up states (p < .05 by paired t test).
after the start of the program she sometimes refused the learning tasks, but after 6 months she started to come to the learning center by herself. In the early stages she came to the learning center in her pajamas; later, she came dressed in regular daytime clothing. As learning became more natural for her, she began to express thanks for the care given to her, her expression relaxed, and she began to smile in her daily life.

Discussion

In this study, we demonstrated that a training program in reading and arithmetic problems, named a Learning Therapy, was effective in dementia care for the improvement of cognitive functions. All of the experimental participants showed improvement in verbal communications with the nursing staff. In addition, significant improvement was observed in verbal conceptualization with regard to the FAB. It is also important to note that cognitive ability measured by MMSE did not decline during the 6-month learning period.

The term rehabilitation is defined as a process of active changes aimed at enabling people who are disabled by injury or disease to maintain an optimal level of physical, psychological, and social functions (26). Recently, in line with this view, cognitive rehabilitation approaches for people with dementia have been introduced. Because memory impairment is a common attribute of any dementia subtype, most of the intervention programs for dementia care have been focused on memory training (3–6). Learning Therapy has two significant characteristics that distinguish this method from previous methods of cognitive rehabilitation. One is that this method is not an evidence-based method; it relies on the theoretical background of the knowledge of neuroscience research—that is, solving arithmetic problems and reading aloud activate bilateral dorsolateral prefrontal cortex of humans. The second is that it aims to mediate transfer of the different cognitive functions within the dorsolateral prefrontal cortex—that is, from reading aloud and solving arithmetic problem functions toward general cognitive functions such as communication, independence, and conceptualization. Although in the present study, DAT patients showed improvement in the several cognitive functions following daily training in reading aloud and solving arithmetic problems.

It has been widely recognized that one of the significant functional roles of the dorsolateral prefrontal cortex is to carry out executive functions. The executive functions mediated by the frontal cortex involve planning, selection, and ongoing regulation of behavior (27). A number of studies (28,29) reported a deterioration of the executive functions in DAT, and showed that impairment in performance of a variety of tasks in DAT patients are related to executive dysfunctions (30). In Learning Therapy, daily training is focused on reading aloud and solving arithmetic problems. Reading aloud is accomplished by the combination of several cognitive processes, for example, recognition of the visually presented words, conversion to phonological representation from graphic representation of words, analysis of the meaning of words, and control of pronunciation. Solving arithmetic problems is also accomplished by many cognitive processes, for example, recognition of visually presented numbers, performance of arithmetic operations, and control of hand movements. It is obvious that both reading aloud and solving arithmetic problems require executive functions. Neuropsychological studies of children with cognitive disorders indicated that reading disability (31–34) as well as arithmetic disability (35,36) is related to the impairment of executive functions. In the present study, significant improvement was observed in verbal conceptualization with regard to the FAB in the experimental group. The verbal conceptualization test was designed to measure the ability to identify abstract categories (24). Abstract category is impaired in frontal damage (37), is investigated by the Wisconsin Card Sorting Test, which is commonly used and considered as an important indicator of frontal dysfunction (38), and is one of the important aspects of executive function (39). Therefore, in the case of Learning Therapy, one possible explanation for the transfer of cognitive functions is the improvement of executive functions during the course of training.

The other important result of Learning Therapy is improvement in communication between nursing staff and participants. Because immediate feedback of participants’ performance was required during Learning Therapy, this therapy improves face-to-face verbal communication, and the communication behavior of the nursing staff changed during the course of the daily trainings.

It was suggested that, in general, the quality of staff–resident communication is often observed to be less than optimal (40–43). Because nursing home staff perceive themselves as too busy to talk with the residents, they are noted to have low expectations of the residents, leading to low levels of social interaction. The residents themselves perceive the staff as too busy to engage in conversation, and feel that they should not bother them unnecessarily (44–46). Cognitive impairments are correlated with decreased engagement, conflict, and distress in nursing home residents (47,48), and changing the communicative behavior of the nursing staff could have a strong positive impact on the residents (49). Therefore, in the present study, improvement of the cognitive function, particularly communication, of the learners may well have resulted from the increased opportunity for staff–learner communication in daily care. This point is one of the limitations of interpretation of the results of our study. In this study, we were not able to distinguish whether the source of benefits for the experimental group was the cognitive training itself, the interaction with the experimenters working with the experimental group, or the additional attention received by the experimental group from the nursing home staff. Future investigations attempting to determine the role of social, emotional, and cognitive factors in the training effect are necessary.

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