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Effect of Age on the Human Ability to Identify Fragmented Letters through Visual Interpolation
(視覚内挿を通じて断片文字を同定する能力に対する年齢の影響)

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Original Paper

Effect of Age on the Human Ability to Identify Fragmented Letters through Visual Interpolation

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ABSTRACT

Humans are skilled at visual interpolation, as in the identification of incomplete letters, e. g., fragmented letters. We examined whether aging would influence the ability to identify incomplete letters in 56 healthy volunteers aged 20–76 years. Fragmented letters of the English alphabet (black, 72-point, MSP Gothic) were randomly displayed one by one on the screen of a personal computer : each letter appeared once per test. Each of the letters was presented within a square (128×128 pixels) against a white background for 200 ms. The fragmented letters were produced by randomly removing rectangular areas (about 4×8 pixels) from complete letters. The rectangles removed were not oriented horizontally but randomly rotated. The scores on performance in reading fragmented letters were above 80% correct identification for the removal of 50% of pixels in all subjects ; however, correct identification scores significantly ($p<0.001$) decreased along with the removal of 70%, 80%, and 90% of pixels, without any substantial difference between men and women or across different age subjects ranging from 20 to 76 years. These results suggest that the ability to identify fragmented letters was well preserved in healthy elderly individuals with normal aging and might be used to evaluate some aspects of cognitive function (language ability).

INTRODUCTION

In general, early detection of cognitive disorders is vitally important for therapies intended to arrest and prevent the progress of dementia, as with some diseases of other organs[1)]. To achieve early detection, it is initially necessary to differentiate patients with asymptomatic or silent disease from healthy individuals. Cognitive function consists of the major elements of neuropsychological function,

Key words : Cognitive function, Dementia, Letter identification, Visual system, Working memory

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Table 1　Groups characteristics

Population	n	Mean age (range)	Women/Men
20s	11	24.0 (20-28)	4/7
30s	12	32.9 (30-37)	7/5
40s	8	45.5 (40-49)	7/1
50s	9	56.3 (50-59)	7/2
60s	9	64.2 (62-67)	4/5
70s	7	73.7 (72-76)	2/5

including attention, memory, language, visuospatial skills, executive ability, and so on[2). Although several assessments of cognitive and intellectual functions in subjects are used in clinical routine examinations[3~5), these tests, for example, differentiating between a psychiatric and a dementia disorder, are often difficult and require a psychiatrist with geriatric expertise. Moreover, these qualitative assessments, which depend on the experience of the observers, are not appropriate measures for examining a large number of subjects because they are time-consuming and costly; therefore, a simple and inexpensive method which can identify and screen subjects with a symptomatic or asymptomatic cognitive disorder at an early stage without a medical specialist is needed. Accordingly, we previously developed a computer-based system for presenting fragmented letters of the English alphabet and quantified the ability of subjects to identify incomplete letters[6). The study demonstrated that the simple evaluation of subjects by their performance in indentifying fragmented letters could be useful for quantifying visual interpolation capability involved in the complexity of the cognitive system; however, the effect of normal aging on the ability to identify fragmented letters remains unclear. It is clinically important to examine whether the ability to identify fragmented letters changes in the elderly, since there is evidence that the results of cognition tests on both retrieval and encoding in the memory process inversely correlate with advancing age[2).

The purpose of the present study was to examine the effect of age on the ability to identify fragmented letters. We hypothesized that normal elderly subjects would show a substantial reduction in the ability to identify fragmented letters through which age-related changes in some aspects of cognitive function are involved in neuropsychological processes.

METHODS

1　Subjects

Twenty-five healthy men and 31 healthy women, ranging in age from 20 to 76 years, participated in the present study (**Table 1**). Their education differed in length and degree between subjects; e. g., from junior high school to graduate school. All subjects were fully informed about the procedures, risks, and benefits of the study, and written informed consent was obtained from all subjects before the study. None of the subjects had any history of cardiovascular or respiratory disease, and all had normal electrocardiograms and blood pressure. All subjects had normal visual acuity. Each participant was given time to become accustomed to test trials during a separate trial about 60 min before the start of the formal study. The study was approved by the university institutional board.

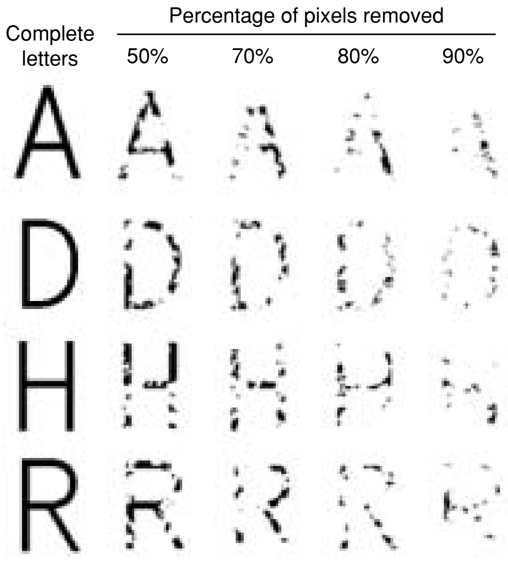

Fig. 1 Original completed letters of the English alphabet were black, 72 point, and in MSP Gothic font
Fragmented letters "A, D, H, and R" with four grades of coarsening were created by removing pixels in a rectangular area (4×8 pixels). The rectangles were randomly rotated instead of being maintained in constant orientation.

2 Stimuli

Using our computer-based system[6], 26 fragmented letters (black, 72-point, MSP Gothic) of the English alphabet were randomly displayed one by one on the screen of a personal computer (Compaq nx9000 ; Hewlett-Packard) with an LCD resolution of 1024×768 pixels and 32-bit color codes. Each letter was presented in the middle of a square (128×128 pixels) against a white background. The fragmented letters were produced by randomly removing a number of small rectangular areas (4×8 pixels) from complete letters. The rectangles removed were not oriented horizontally, but were rather rotated randomly. **Fig. 1** shows examples of fragmented letters "A, D, H, and R" with different levels of coarsening. In our previous study[6], fragmented letters were evaluated with respect to the density of information provided by the pixels that constituted the letters according to information theory[7]. These results demonstrated that the percentage of pixels removed from the complete letters was directly proportional to the density of information about the removed pixels ; therefore, for simple and easy analysis, the degree of coarsening of fragmented letters was defined as the ratio of pixels removed to the total pixels in the complete letter.

3 Experimental design

Each subject was seated in a comfortable chair and required to maintain a constant horizontal distance between their eyes and the display monitor during rest and test periods. The subjects underwent tests to identify 26 fragmented letters at four grades of difficulty (removal of 50%, 70%, 80%, and 90% of pixels). The difficulty of the tests used to identify letters increased with the grades of

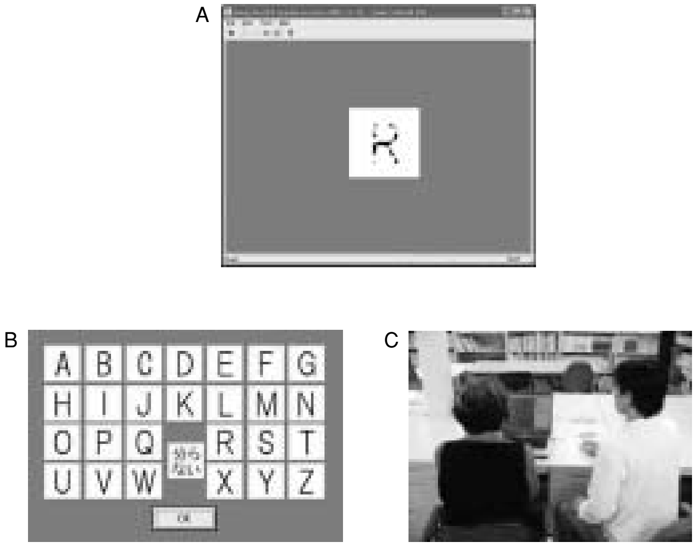

Fig. 2　A：Example of a fragmented letter displayed on a computer screen
Each letter was presented for 200 ms.
B：Answer board
The subject was asked to verbally identify the letter that matched the fragmented letter. The Japanese phrase "分らない" means "I do not recognize the letter".
C：Experiment in progress

coarsening[6]. Each of the 26 letters was randomly displayed once per test and the duration of each presentation was set at 200 ms (**Fig. 2A**). The subjects were required to select one letter from an answer board on the display after each presentation (**Fig. 2B**). At that time, they answered verbally or indicated the letter. The subjects answered letters at their own pace, since they were not given any instruction that they should respond to the stimuli as quickly as possible ; thus, errors as a result of quick decisions induced by time pressure were eliminated. The subjects were not given feedback regarding the correctness of their selection during the tests. The subjects also did not receive either a reward or punishment during the tests. Each subject underwent four trials sequentially, which consisted of four grades of coarsening by pixel removal. The intervals between the four trials were about 5 min as a rest period.

4　Statistical analysis

The data were analyzed using three-way analysis of variance for repeated measures with the main factors of sex, age, and fragmentation grade of letters. Since the two-way interactions (Sex×Age and Sex×Grade) were not statistically significant, data for men and women were combined. When a significant F ratio was observed, the post-hoc Scheffé's test was used to identify significant differences. Differences were considered significant for all statistical analyses at $p<0.05$. Data are presented as the mean±SD, if necessary.

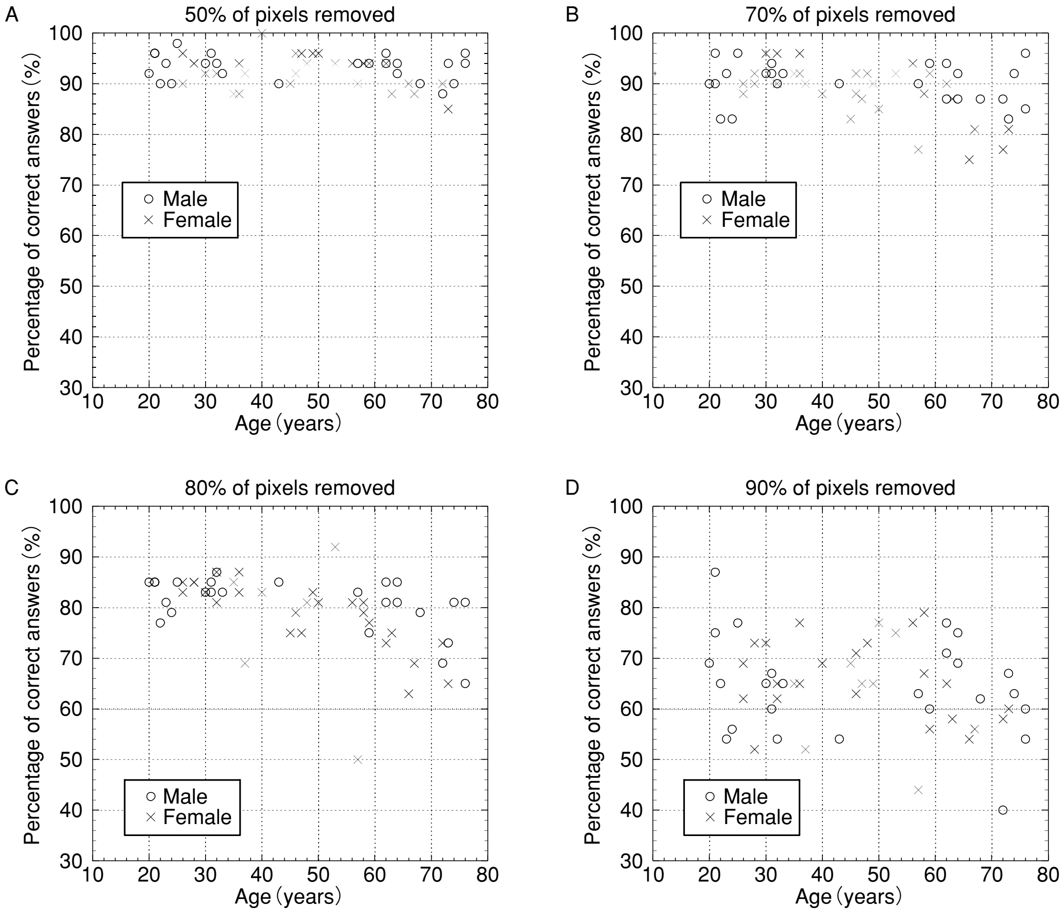

Fig. 3 Relationship between the percentage of correct identifications and the percentage of pixels removed for four grades of difficulty in identifying fragmented letters against age

Each symbol represents one subject (open circles : men, n=25, crosses : women, n=31).

RESULTS

Fig. 3 shows the relationship between the percentage of individual correct answers and the percentage of pixels removed to create fragmented letters against age. All subjects scored well when identifying fragmented letters, with ＞80% correct identification for 50% of pixels removed, irrespective of age (**Fig. 3A**). However, the percentage of individual correct answers gradually decreased as the percentage of pixels removed rose from 70% to 90% (**Figs. 3B to 3D**), whereas interindividual differences in the percentage of correct answers increased with the removal percentage. In particular, the correct identification scores with the removal of 90% of pixels ranged between 40% and 87%.

For statistical analysis of age-related change in the correct identification scores, the subjects were divided into three age groups : 20–37, 40–59, and 62–76 years. **Fig. 4** shows a comparison of changes in correct identification scores for the four grades of coarsening fragmented letters according to three age groups. There were significant ($p < 0.001$) decreases in mean values for the percentage of correct

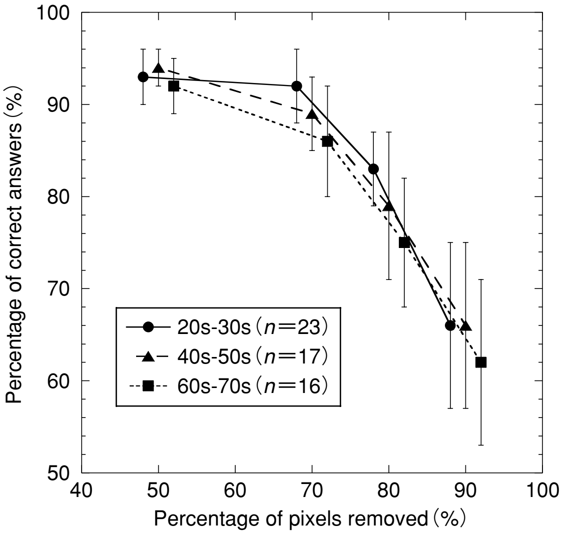

Fig. 4 Changes in the scores of correct identifications of fragmented letters versus the percentage of pixels removed in different age groups : 20s-30s, 40s-50s, and 60s-70s

answers against the percentage of pixels removed in each group (**Fig. 4**) ; however, the patterns of decreases in mean values were not significantly (p=0.308) different among the three age groups.

DISCUSSION

Comparison of healthy young and elderly adults ranging in age from their 20s to 70s demonstrated no significant difference in the percentage of correct identification of fragmented letters with the removal of 50%, 70%, 80%, and 90% of pixels. These results suggest that humans with normal aging have no significant change in ability to identify fragmented letters, reflecting that the capability of visual interpolation is preserved in the aging process. Fortunately, these results do not support our hypothesis that the ability of normal elderly subjects would substantially decline with age in the identification of fragmented letters through age-related changes in some aspects of cognitive function.

Cognitive functions are largely divided into several domains, which are characterized by neuropsychological functions : attention, memory, language, visuospatial skills, and executive ability[2,8]. Clearly, these abilities and their combinations are necessary to identify fragmented letters. In this study, letter-identification tests required the subjects to maintain contact with visual stimuli (fragmented letters) and to identify the correct letters on an answer board, using sequential behaviors of sustained attention and selective attention, respectively. Short-term or working memory with the acquisition and brief retention of fragmented information is involved in the selection and determination of the correct letters corresponding to the fragmented letters[2]. A deficit in the ability to recall visual information after a short-term delay is reported to be a very sensitive indicator of early dementia[9]. Visuospatial functioning may be also implicated in the identification of fragmented letters, since it is responsible for the ability to perceive, construct, and manipulate visual information as a geometrical form rather than a verbal nature[10]. By considering the direct and indirect relevance of visual, attention, and language functions, the evaluation of fragmented-letter identification using the present system may offer insights into an important aspect of cognitive process via the visual system.

Individuals have different educational backgrounds, and their quantity and quality of learning therefore differ[11]. It is generally known that performance scores in reading and writing in language tests largely depend on the educational status of individuals. However, the present study demonstrated that despite the different educational background of subjects, the letter-identification scores were similar between the young and elderly ranging in age from 20 to 76 years. This suggests that some aspects of linguistic ability with age in normal subjects are well preserved and adjustment of standardized scores is not probably required for subjects of different ages and educational levels.

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