Development of New Auditory Testing Media with Invisible 2-Dimensional Codes for Test-Takers with Print Disabilities

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Abstract. Utilizing invisible 2-dimensional codes and digital audio players with a 2-dimensional code scanner, we developed two types of new auditory testing media. The result of experimental evaluation of the new testing media shows that, in addition to existing special accommodations such as large-print-format test and braille-format test, the introduction of the new auditory testing media enables all test-takers with print disabilities, including the newly blind, the severely partially sighted and the dyslexic, to take the National Center Test for University Admissions.

1 Introduction

The National Center Test for University Admissions is the joint first stage achievement test for admissions into all national and local public universities as well as many private universities in Japan. Every year, about 550,000 students take it. As for test-takers with disabilities, special accommodations regarding testing media such as large-print-format test and braille-format test have been administered [1]. However, auditory testing media have not been available yet. In most advanced countries, auditory testing media such as human readers, audio cassettes or computer screen readers are available for test-takers with print disabilities [4, 5].

It is necessary to develop new auditory testing media for the National Center Test. It is almost impossible to take the National Center Test with ordinary types of auditory testing media because the documents are very long and the document structure very complicated. Computer screen readers often misread some combinations of Chinese characters in Japanese documents.

For auditory testing media for the National Center Test, the utilization of DAISY (Digital Audio Accessible Information System) and Tablet PC has been

studied [2]. DAISY is a world standard audio system for people with visual disabilities. Test-takers can listen to the document from any point, such as from an underlined or blank part, without delay. They can also use the talk-speed-control function. However, DAISY is not convenient enough for tests which have complicated document structure. On the other hand, tablet PC has been identified as appropriate testing media [2]. However, there are difficulties in administration because security of test administration and prevention of machine trouble cannot be ensured.

Utilizing invisible 2-dimensional codes and digital audio players with a 2-dimensional code scanner, we developed two types of new auditory testing media for test-takers with print disabilities. In 2009, auditory tests of speech sounds on document structure diagrams were developed [3], and, in 2010, multimodal tests of speech sounds on ordinary texts were developed.

Experiments were conducted to evaluate the two types of new auditory testing media. The result shows that, in addition to existing special accommodations such as large-print-format test and braille-format test, the introduction of the new testing media enables all test-takers with print disabilities, including the newly blind, the severe partially sighted and the dyslexic, to take the National Center Test for University Admissions.

2 Two Types of New Auditory Testing Media

Using the two types of new auditory testing media, tests can be administrated only with digital audio players and paper booklets (Fig. 1). The introduction of invisible 2-dimensional codes enable us to develop the new testing media.

We employ 'GridOnput', an invisible 2-dimensional code system developed by Gridmark Solutions Co., Ltd (Fig. 2, left). Dots of GridOnput are arranged at intervals of about 0.25 mm. The size of a code is about 2 mm square. Since the intervals are large enough for the size of dots themselves, dots are almost invisible. If we use invisible ink, which absorbs only infrared light, instead of black ink, dots become totally invisible.

As a reading device for the new auditory testing media, we employ 'Speaking Pen' developed by Gridmark Solutions Co., Ltd (Fig. 2, right). Speaking Pen has a 2-dimensional code scanner at its top. When a 2-dimensional code is scanned with Speaking Pen, the corresponding speech sound is reproduced. We can listen to the sound through a headphone or built-in speaker. The sound volume and speed can be adjusted with its buttons mounted at the front side. The sound data is stored in an SD memory card. 1G byte is enough to store all sound data of 1-year amount of the National Center Test.

2.1 Auditory Tests of Speech Sounds on Document Structure Diagrams

For newly blind test-takers, partially sighted test-takers and dyslexic test-takers who can read neither braille nor printed characters, auditory tests of speech sounds on document structure diagrams were designed [3].

Fig. 1. Test Scene

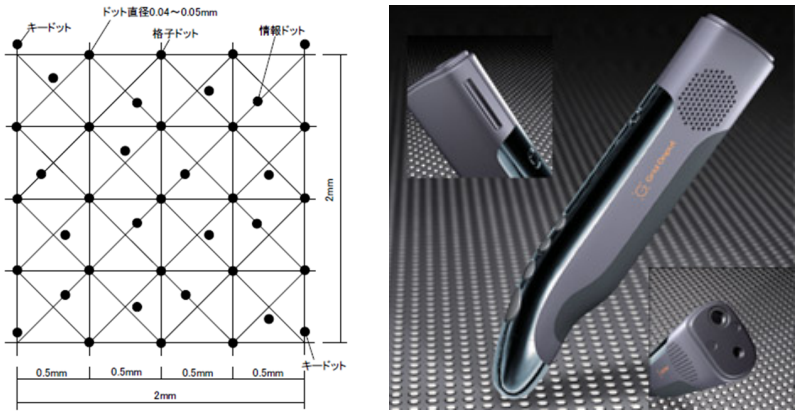

Fig. 2. 2-Dimensional Code (left), and Speaking Pen (right)

Document structure diagrams represent the organization of test documents. Fig. 3 (left) is an example of a document structure diagram in the Japanese language. Each document structure diagram of a problem can be arranged within a sheet of paper. The first line shows the subject name 'Kokugo 1' and the second line the problem number 'Dai 2 Mon'. The upper part shows the document structure of the theme document of the problem. Each line '(1)'-'(3)' corresponds to a paragraph in the theme document. The symbol '—' represents a sentence in a paragraph, and the symbols 'a'-'e' represent underlined parts of the theme document. The lower part shows the document structure of the questions of the problem. Each line 'Toi 1'-'Toi 2' corresponds to a question. The numbers '3'-'4' represent answer items, and the number symbols '1'-'4' represent multiple-choice answers for an answer item.

Document structure diagrams and corresponding invisible 2-dimensional codes are printed on white paper by an LED printer (OKI Data Corporation). Braille characters and braille lines may also be embossed on the same paper over-

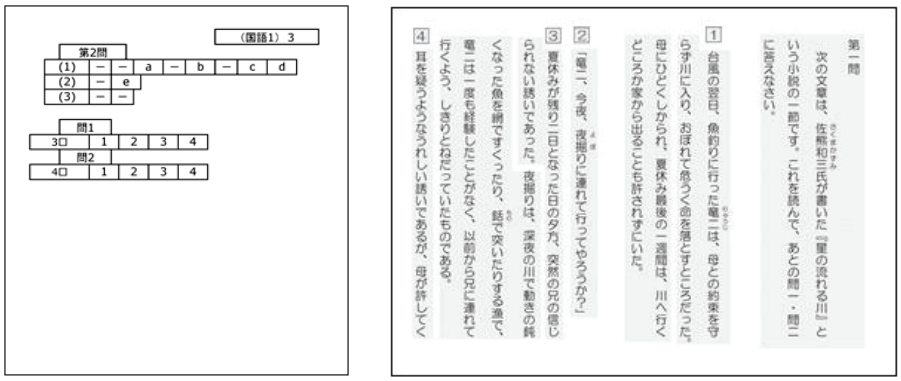

Fig. 3. Document Structure Diagram (left), and Ordinary Text with 2-Dimensinal codes (right)

lappingly for newly blind test-takers. When any part of a document structure diagram is touched by a digital audio player with a 2-dimensional code scanner, the invisible code is scanned, and the corresponding speech sound is reproduced.

2.2 Multimodal Tests of Speech Sounds on Ordinary Texts

For dyslexic test-takers and partially sighted test-takers who can read some printed characters, multimodal tests of speech sounds on ordinary texts were designed.

In a test-booklet of multimodal tests of speech sounds on ordinary texts, normal characters or large-print characters are printed overlappingly with corresponding invisible 2-dimensional codes. Fig. 3 (right) is an example of a page of a test-booklet.

Similarly to the document structure diagrams, when any part of the texts is touched by a digital audio player, the invisible code is scanned, and the corresponding speech sound is reproduced. Paragraph numbers are prepared so that test-takers can reproduce the speech sound of each paragraph.

3 Evaluation Experiment

3.1 Experimental Design for Partially Sighted Subjects and Dyslexic Subjects

The experimental design is a repeated 3x3 Graeco-Latin square method.

The partially sighted subjects are 9 partially sighted high school students including some fresh graduates. The median of their corrected visual acuity is 0.08. They are divided into three subject groups. The dyslexic subjects are 9 dyslexic adults. Only one of them is a high school student because it was difficult to find dyslexic high school students in Japan. They are also divided

into three subject groups. There are three testing media: large-print-format test, auditory test of speech sounds on document structure diagrams, and multimodal test of speech sounds on ordinary texts. The speech sounds are recorded as natural voice. Problems are from three study subjects: Japanese, English, and mathematics. The test procedure is administered without time limits.

3.2 Experimental Design for Braille User Subjects and Nondisabled Subjects

The braille user subjects are 15 students from a high school for the blind. The nondisabled subjects are 21 high school students. Both of them are divided into three subject groups. There are three testing media: braille-format test, auditory test of speech sounds on document structure diagram with recorded human voice, and auditory test of speech sounds on document structure diagram with computer-synthesized voice for the blind subjects. The nondisabled subjects take ordinary text tests instead of braille-format tests. Problems are from the same three study subjects: Japanese, English, and mathematics. The test procedure is administered without time limits.

3.3 Results on Distributions of Score

In Fig. 4 (1), Fig. 4 (2), and Fig. 4 (3), the box-and-whiskers plots of distributions of score of three testing media for each study subject are shown. The box-and-whiskers plots are sorted by the median of score.

The vertical lines on the right-hand side of plots represent the results of Scheffe's method of pair wise multiple comparison. There is no significant difference among box plots tied by a line or significant difference between them not tied by a line.

We can see similar tendencies of the testing media among the three study subjects.

As a result of Scheffe's method of pair wise multiple comparison, there are no significant differences among the distributions of score concerning the testing media for each subject group in each study subject except the distributions of score for nondisabled in English.

As a result of Mann-Whitney's test, we can see that learning achievement levels are almost similar among the four subject groups for Japanese, English and Mathematics because there are no significant difference among distribution of score for braille-format test of the blind group, that for large-print-format test of the partially sighted group, that for large-print-format test of the dyslexic group, and that for ordinary format test of the nondisabled group.

3.4 Results on Distributions of Answering Speed

In Fig. 5 (1), Fig. 5 (2), and Fig. 5 (3), the box-and-whiskers plots of distributions of answering speed of the testing media for each study subject and the results

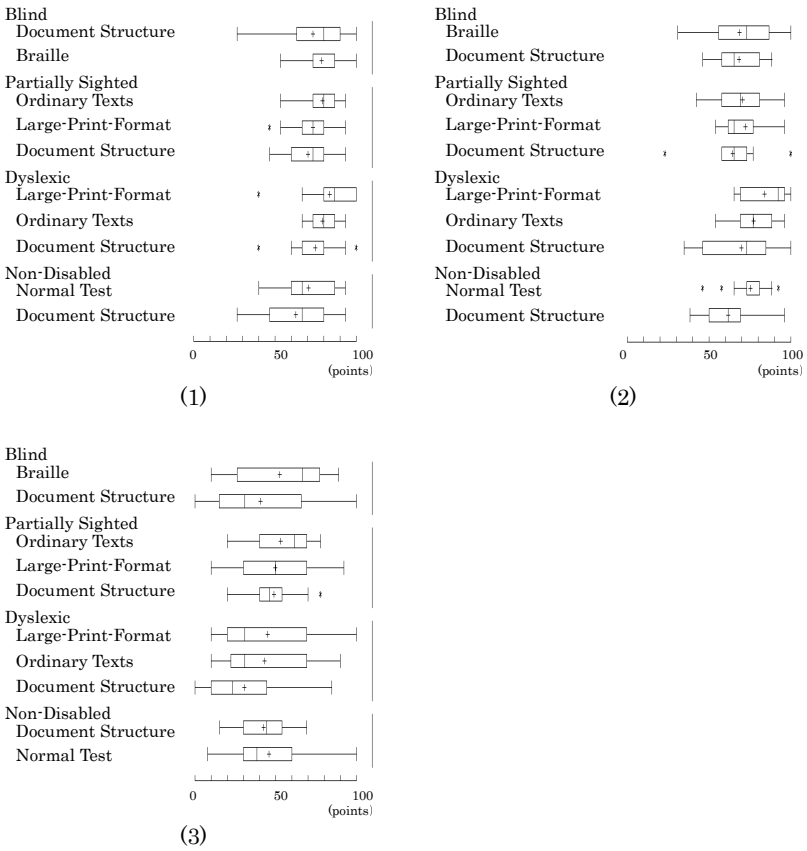

Fig. 4. (1) Distribution of Score of Japanese, (2) Distribution of Score of English, and (3) Distribution of Score of Mathematics

of Scheffe's method of pair wise multiple comparison are shown. The box-and-whiskers plots are sorted by the median of answering speed.

As a result of Scheffe's method of pair wise multiple comparison, the distributions of answering speed of auditory tests of speech sounds on document structure diagram are significantly slower than that of the other testing media for each study subjects.

As a result of Mann-Whitney's test, distribution of answering speed of ordinary format test for the nondisabled group is significantly faster than that of other test media for the print disabled groups in each study subjects.

3.5 Discussion

The result of experimental evaluation of the new testing media shows that, in addition to existing special accommodations such as large-print-format test and braille-format test, the introduction of the two types of new auditory testing

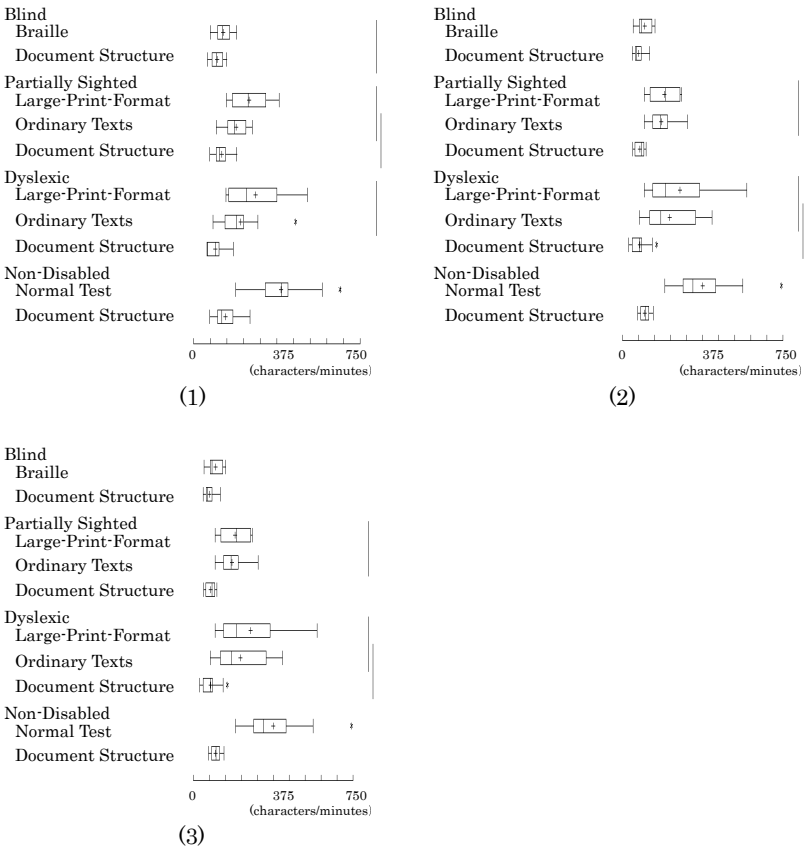

Fig. 5. (1) Distribution of Answering Speed of Japanese, (2) Distribution of Answering Speed of English, and (3) Distribution of Answering Speed of Mathematics

media enables all test-takers with print disabilities to take the National Center Test for University Admissions. Test-takers with print disabilities can get the same score as nondisabled test-takers for Japanese, English and Mathematics if the learning achievement levels of them are the same. Answering speeds of the nondisabled group are significantly faster. However, the disabled and the nondisabled can take a test fairly if we put adequate time limit of a test for each test-taker with print disabilities.

4 Conclusion

Utilizing invisible 2-dimensional codes and digital audio players with a 2-dimensional code scanner, we developed two types of new auditory testing media: auditory tests of speech sounds on document structure diagrams [3], and multimodal tests of speech sounds on ordinary texts.

The result of the experimental evaluation shows that, in addition to existing special accommodations such as large-print-format test and braille-format test, the introduction of the two new testing media enables almost all test-takers with print disabilities to take the National Center Test for University Admissions.

When auditory tests of speech sounds on document structure diagrams become practical, the newly blind and the severely partially sighted can take the National Center Test. Test-takers do not have to be able to read braille to take auditory tests of speech sounds on document structure diagrams because the shape of the document structure diagrams helps enough to guide the positions of 2-dimensional codes to scan. Actually, such newly blind students can take the test in the experimental evaluation.

With multimodal tests of speech sounds on ordinary texts, the partially sighted and the dyslexic can actively and efficiently read texts taking advantage of the modality characteristics of speech sounds and ordinary texts.

In addition, the easiness of administration and security management of the new testing media is noteworthy. Tests can be administrated only with a digital audio player with 2-dimensional code scanner and paper booklets on which document structure diagrams or ordinary texts and corresponding invisible 2-dimensional codes are printed. When machine trouble happens, tests can be continued with a replacement of a digital audio player. Price of a digital audio player is reasonable (about 30 euro).

As a future work, the authoring system of computer-synthesized speech voices and test-booklet with invisible 2-dimensional codes should be developed. We want to make the two types of new testing media practical within 3 years.

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