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A Mental Cutting Test on Female Students Using a Stereographic System

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Abstract. A stereographic mental cutting test (hereafter SMCT) was conducted to analyze 3D spatial abilities evaluated by a standard mental cutting test (hereafter MCT). The results of the analysis indicated that the MCT mainly reflects the abilities in making and manipulating three-dimensional mental images. The results also indicated that the subjects came to recognize 3D shapes more easily by using stereograms. However, the stereograms did not have any effect on complicated mental image processing tasks such as transformation of a section to a true shape view. Also, low scoring subjects in this study could not recognize the test solid and its cutting plane well, and they were unable to form correct images of objects, even when they used stereograms.

Key Words: mental cutting test, female, stereogram

MSC 1994: 51N05

1. Introduction

In courses on graphics at the undergraduate level of study, 3D spatial abilities have received much attention lately. In fact, for the past decade, several spatial ability tests have been given to evaluate spatial abilities of students. The MCT (a sub-set of CEEB Special Aptitude Test in Spatial Relations, see [1]) was used by SUZUKI et al. [2] for measuring spatial abilities in relations to graphics curricula. Since then the MCT has been widely used for this purpose and a large amount of data have accumulated from tests conducted on various subjects .

The standard MCT consists of 25 problems for which the full score is 25. In each problem, subjects are given a perspective drawing of a test solid which is to be cut with an assumed cutting plane. Subjects are asked to choose one correct cross section among 5 alternatives. There are two categories of problems in the MCT (SUZUKI et al. [2]). One category is called "pattern problem", in which the correct answer is determined by identifying only the pattern of the section. The other is called "quantity problem", in which the correct answer is

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determined by identifying not only the pattern but also the quantity in the section, e.g., the length of the edges or the angles between the edges. It was shown by SAITO et al. ([3], [4], [5]) that in order to solve the MCT problems, subjects go through 3 phases of information processing, which are,

(1) Recognizing the solid from the perspective drawing,

(2) Cutting the solid by the assumed cutting plane, and

(3) Judging the characteristic quantity of the section, if necessary.

As for recognition from a projection drawing such as perspective, there may exist a difficulty caused by its paradoxical nature. A projection drawing is a chart consisting of a set of lines on a 2D surface and represents an image of a 3D object, which by its very nature can not exist on a 2D surface.

At the same time a projection drawing represents not an unique 3D shape but all possible 3D shapes in which every corresponding points are on the same projection lines. Our perceptions, however, usually make a fairly reliable judgment, or select proper "object hypothesis" against the object through the process of sensing the most possible object. Some of the objects among the MCT problems have, however, not so usual and common shapes.

The above discussion suggests that with perspective drawings like those in the problems in MCT, there may exist various factors, which may cause subjects to fail in recognizing the proper objects correctly.

Therefore, if the test solids are shown in the form of stereograms which approximate stereopsis, i.e., a depth sense based solely on stimulation of disparate locations on the retinae, the recognition process might be assisted and errors associated with phase (1) might be reduced. NISHIHARA et al. [6], [7] replaced the perspective drawing of the test solid in the MCT with an anaglyphic stereogram with red-green glasses in order to evaluate how much an anaglyphic view is able to assist subjects in solving spatial solving problems. A similar system was proposed by YAO et al. [8]. They presented a stereographic MCT system using a time-sharing display controller, glasses with synchronized liquid crystal shutters and a microcomputer. They compared the results of the SMCT with those of the standard MCT using a microcomputer network that has been developed by SUGAI et al. [9]. They showed that for the SMCT,

(1) the mean score was a little bit higher although there was no significant difference between the two tests,

(2) correct response rates of pattern problems had a tendency to increase, but those of quantity problems did not change.

However, most of the subjects in their research got extremely high scores. The correct response rates for 16 problems out of the 25 were over 90% and there were only 4 problems whose correct response rates were under 80%. Therefore, it was considered that the results might not reflect the true relation between the two types of tests because of the small number of subjects who could get higher scores in the SMCT.

In this research, the SMCT was conducted on female subjects, who are much less likely to get high scores in the standard MCT (TSUTSUMI [10], KASHIMA [11]). The results, together with the results of the standard MCT, were analyzed to get some insight to spatial abilities evaluated by the MCT.

2. Methods

2.1. Stereographic MCT

The SMCT system designed by Yao et al. [8] was used in this study. The system includes a Crystal Eyes Process Controller, glasses with liquid crystal shutters, a color display and a microcomputer. The system presents alternately two different perspective views of the test solid on the display. The two views are drawn based on the principle of binocular disparity. The opening and shutting of the shutters for each eye built in the glasses are synchronized with the renewal of presentation of the perspective views. The results of the test include response time for each problem and the choice of alternatives made by the subject.

2.2. Standard MCT

The standard MCT using a microcomputer network (hereafter PMCT) developed by Sugai et al. [8] after making the necessary changes to make it run on Windows 95© was used as a control. In this system, perspective drawings of test solids were shown. The results of the test include response time for each problem together with the choice of alternatives made by the subjects.

2.3. Subjects

Seventy subjects participated in the SMCT and 51 subjects in the PMCT during the period of October to November, 1997. All the subjects are female students in the first and the second grade at the School of Social Information Studies, Otsuma Women's University.

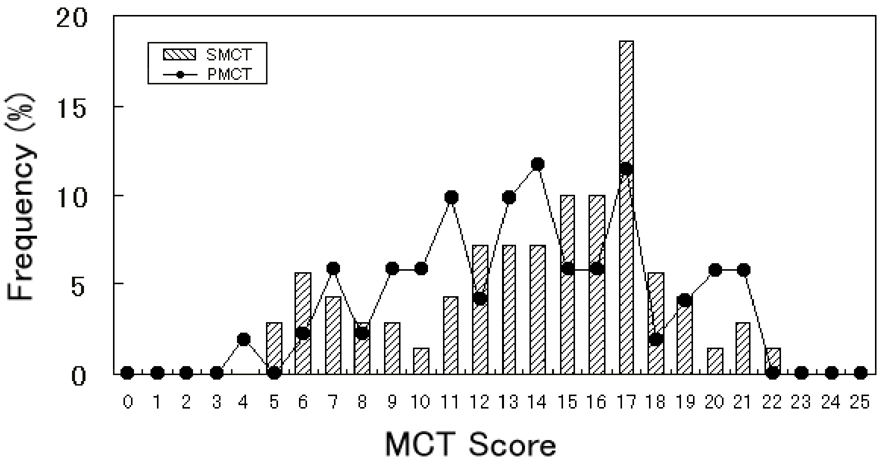
3. Results and discussion

3.1. Mean scores

Mean scores for the SMCT and PMCT were 13.97 ($SD = 4.22$, $N = 70$) and 13.68 ($SD = 4.23$, $N = 51$), respectively. Though there was no significant difference between the mean scores of the two tests, the distribution of scores of SMCT showed a tendency to be somewhat higher than that of scores of PMCT (Fig. 1). These results agree with those of experiments by Yao et al. [8] in which mean scores were 21.87 ($SD = 2.05$, $N = 61$) and 21.35 ($SD = 2.77$, $N = 333$), respectively. As there is a difference of about 8 points (out of a possible 25 points) between the mean scores of present experiments and their experiments, we will consider the subjects in their study to be a "high scoring group" and those in the present experiments to be a "middle scoring group".

3.2. Correct response rates for each problem

Fig. 2 shows correct response rates for each problem. Correct response rates on the SMCT increase significantly ($P > 0.05$) for problems 5, 7, 12, and 14 and decrease significantly ($P < 0.05$) for problems 18, 19, and 23. These problems are pattern problems except for 23. Correct response rates do not increase significantly ($P < 0.05$) in quantity problems. These results agree with the results given by Yao et al. for the problems for which the correct response rates show significant difference between two tests, i.e., problems 12 and 23. In their study, other problems showed no significant differences except problem number 9. As was


SMCT
PMCT
Frequency (%)
20
15
10
5
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
MCT Score