MEASUREMENT OF ATTENTIONAL PERFORMANCE TOWARDS THE REDUCTION OF HUMAN ERRORS BY NEWLY DEVELOPED "COMPOUND DIGIT CHECK TEST (CDCT)"

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In this report, we introduce our newly developed test named "Compound Digit Check test (CDCT)". This test has been developed for easy measure of the characteristics of human attentional control in order to reduce human errors in various workspaces. Two researches of CDCT are reported in this paper: One is the analysis of changes in attentional control characteristics due to aging, and the other is the investigations for whether CDCT could be used as a training tool. As the results of these investigations, it is revealed that the aging selectively deteriorates the switching of attention from local to global, and CDCT also has the aspect of the training tools as well as the measuring of human attentional control. We conclude that CDCT can be a useful test for preventing the human error occurrence by measuring and training individual workers' attentional performance.

INTRODUCTION

In order to prevent human error effectively, it will be required to measure the individual worker's information processing characteristics and to feed back these characteristics to the workers. Especially, attentional performance has a close relation with the occurrence of human error. Therefore, it is very important to investigate the characteristics of attentional performance. However, simple and appropriate tests that can measure the attentional characteristic accurately have not been developed yet.

When we planed to develop a new test, we focused on the global-local properties of visual information processing, since most visual stimuli have multilevel structures. For instance, a human body as a global shape consists of several local components such as head, arms, torso, and legs. Moreover, a head consists of some of local parts, eye brows, eyes, nose, mouth, and ears. Many instruments used in various workspaces have the same visual structures, and most workers require to pay their attention to such complex information.

Therefore, we developed a new test named "Compound Digit Check test (CDCT) " that can easily measure the characteristics of individual worker's attentional control system, including attentional allocation and switching while they are engaged in visual tasks (Gyoba, Ohashi , and Morikawa, 1999). The compound digit patterns used in this test were modified from the compound patterns developed by Navon (1977).

CDCT comprises 5 or 6 sheets. In each sheet, 144 compound patterns are printed. A compound pattern consisted of a global digit that contained 17-19 local digits. Subjects were required to detect and to check with a pencil a specific number that appears in both global and local levels of the compound patterns, within the time limit of 60 or 80 sec for each sheet. It takes about 15 minutes to complete CDCT including instruction and practices.

Using CDCT, we have investigated the characteristics of attentional performance for over 800 subjects, and have checked the validity and reliability of the test. In this report, we introduce some of the unique aspects of CDCT and indicate wide applicability of the test.

METHOD

Compound Digit Patterns of CDCT

Figure 1 shows some samples of the compound digit patterns. The digits used in the global and local levels were 2, 3, 5, 6, 8, and 9. The global and local digits were combined randomly, but the global digit and the local digits were always different from each other. A local digit was consisted of 3 dots arrangement horizontally and 5 dots arrangement vertically, and a global digit was

depicted within the arrangement of 5×5 local digits.

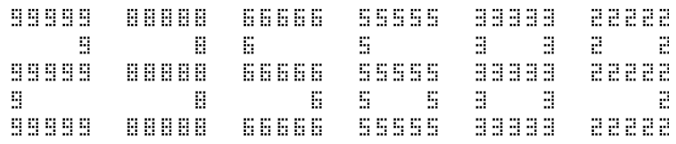

Figure 1: Illustrations of the compound digit patterns used in CDCT. The leftmost pattern consists of a global digit of 2 and local digits of 9.

Test Sheets of CDCT

One sheet of CDCT had B4 paper size (367 mm ×257 mm), and had 18 × 8 compound patterns. In a sheet, 72 targets which subjects had to detect and checked were included (36 targets appeared in local digits and 36 targets in global digits). and the subject's performance was analysed in the following two conditions. One is called "single target condition" which contains no preceeding target on the left side of it, and the other is called "consecutive targets condition" which had preceeding target on the left side of it. Furthermore, the consecutive targets condition were divided into 4-conditions equally (12 targets for each), defined by the combinations of the present target level and the previous target level.

Procedure for CDCT

The task of the subject was to search the compound digit patterns from left-to-right and top top-to-bottom, and to detect and check the patterns if they had target digits (3 or 6) either in the global or the local level. To keep the viewing distance about 50 cm, the subject was instructed to sit properly and to keep leaning one's back to the seat backrest.

After the explanation of the required task, the subjects practiced on about 40 patterns for understanding the task. Then the main test consisting of 6 trials was begun. One trial was done within the time limit of 80 sec, and there was 1 min rest between the trials. The subject required to mark the last compound pattern that he/she watched at the end of the trial. This was necessary for the indication of the amount of the checking work in each trial.

Analysis of the performance on CDCT

Basically, the detection rates were used for the analysis, and these rates were calculated using the following equation in each condition described below.

$$\textit{Detection rate (\%)} = \frac{\textit{number of correctly checked targets}}{\textit{number of all targets within the work}} \times 100$$

For the single target condition, the following two measures were used. G%: Global target detection rate. L%: Local target detection rate. For the consecutive target condition, the following four measurements were calculated. GG%: Global target detection rate after global target. GL%: Local target detection rate after global target. LG%: Global target detection rate after local target. LL%: Local target detection rate after local target . From G% and L%, the tendency of the attentional allocation was measured, and other indicators, especially GL% and LG%, were used for investigating the characteristics of attentional switching.

RESULTS

We have conducted CDCT on more than 800 subjects, and it has been confirmed that the test is much useful for measuring human attentional control mechanisms. We summarized some of the important findings in this paper.

RESEARCH-1: Changes of Attentional Control Characteristics due to Aging

Aims of Reseach-1. Research 1 aimed to investigate how the attentional control to global and local information is modified with age. Although this problem is very important for preventing human errors no consistent results have been shown. For instance, Oken, Kishiyama, Kaye, and Jones (1999) reported that there was a significant impairment in the elders' ability to process global information compared with that of locals. On the other hand, Sullivan (1999) showed that advanced age diminished the availability of local, but not global information.

Subjects. Sixty-five subjects were tested, and their ages ranged from 23 to 54 years, with a mean age of 39.9 years.

Results and discussions. Table 1 shows the results of all subjects. There were tendency that detection of local digits was easier than that of global. In the

consecutive targets condition, LG% indicated the lowest performance, and LL% indicated the highest. These results were general and robust characteristics of CDCT.

Table 1: Means and standard deviations of detection rates for all subjects

	G%	L%	GG%	GL%	LG%	LL%
Mean	85. 89	91.13	87.42	90.51	84.00	93.98
SD	11.12	6.22	11.39	7.58	13.63	8.28

(n=65)

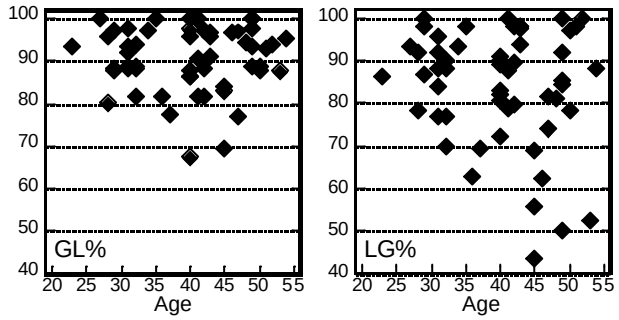

Figure 2: Scattergram of detection rate (%) as a function of age. Left: GL%, Right: LG %. Each symbol signifies the detection rate of each subject.

Interesting characteristics of the age-related changes are revealed by the comparison between GL% and LG% (see Fig. 2). The comparison of these two measures show that individual differences for GL% are relatively small regardless of age, but those for LG% become large with the increase of age. Since these measures indicate the ability or smoothness of attentional switching, we concluded that the aging selectively deteriorate the switching of attention from local to global, namely the expanding of attentional focus. These findings almost agree with the results of Oken et al. (1999).

RESEARCH-2: Possibility for a Training Tools of Attentional Control

Aims of Reseach-2. This research was conducted to reveal whether CDCT has a function of improving subjects' ability of attentional control as well as measuring the characteristics of the attentional mechanisms. Because, when we tried to apply the test to various type of workspaces, we realized that CDCT has another useful possibility as a training tool of attentional control.

For this purpose, we divided the subjects into two groups randomly, one group of subjects were asked to conduct CDCT as a training tool, and the other group of subjects were required to conduct a control training using a simple addition task (for details, see below). Both of groups performed the same attention-related tests for checking their ability before and after the training. If the CDCT training group indicates higher improvement on the transfer tests, we can prospect the aspects of CDCT as an attention training tool.

Subject. Thirty-three subjects were participated in the experiment. All of the subjects were university students. They were divided into two groups randomly, one was CDCT training group (19-subjects), and the other was control training group with the simple addition test (14-subjects).

Simple Addition Test (S.A.T). This test was developed by modifying CDCT sheets: The local digits were changed to block patterns. The task of the subjects was to add the number of adjacent global digits.

Transfer tests. Two kinds of attention-related tests were used for investigating changes of subjects' ability, before and after the training. One was a proofreading test (hereafter, PRT) using newspaper-like documents devised by ourselves, another was the Group Embedded Figure Test (GEFT, see Fig. 3) developed by Witkin, Oltman, Raskin, and Karp (1971)

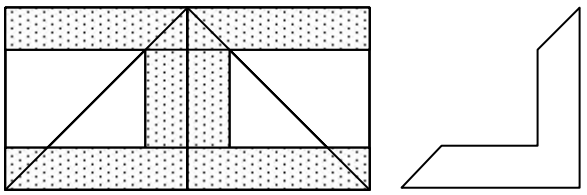

Figure 3: A sample illustration of GEFT. The right figure was embedded in the left figure. The subject was required to find the right in the left pattern.

Procedure. Each of the transfer tests was divided into two parts with equal difficulty, and they were used for the tests before or after the training sessions. Therefore the total experiments have done by three sessions: the 1st session was the checking the basic attentional ability of each subjects, and the 2nd session was for the training by CDCT or SAT, the 3rd session was the checking the improvement of attentional control by the training.

Results and discussions. CDCT and SAT indicated significant improvement by training (see Fig. 4).

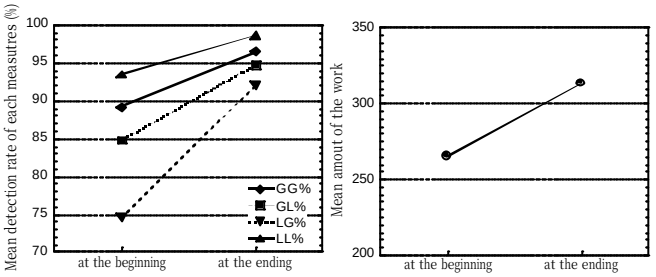

Figure 4: Training effects of two tests. Both of the tests themselves indicated the improvement due to traing (statistically significant; ps<.05). Left: CDCT; Right: Simple Addition Test (SAT)

In analyzing the results of PRT (Figure 5 left), detection rates were calculated for each subject and each condition, and mean of those detection rates were used. Comparison between before and after training, only the CDCT training group had the significant differences (CDCT: $t(17)=2.11$, $p<.05$, SAT: $t(12)=.99$, n.s.; see Fig. 5a).

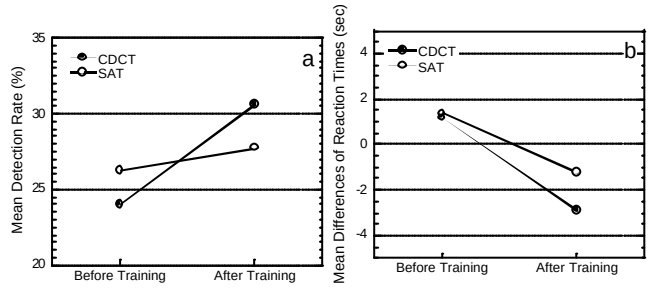

Figure. 5: Changes of attentional performance between before and after training. a: Proofreading test (PRT); b: Group Embedded Figure Test (GEFT)

For analysis of GEFT(Figure 5 right), the differences between the mean reaction time for each figure and reaction time for each subject were used. As the results of statistical differences between before and after training, only CDCT training group had a significant tendency of improvement (CDCT: $t(16)=1.55$, $p<.10$, SAT: $t(13)=1.12$, n.s.; see Fig 5.b)

These results showed that the SAT training only improved the performance of the test itself, but the CDCT training group improved performance in other attention-related tests. These improvements of the CDCT group indicate transfer of "attentional control learning" During doing CDCT, the subjects might learn how to control or switch their attention effectively or swiftly. Therefore we think that CDCT can be a useful tool for training attentional performance

DISCUSSIONS

Considering various kind of workspaces, most workers are required to pay attention to various materials. However, their resources for the attentional mechanisms have severe limitations, so the workers should be a good controller of their attentional performance. To understand their own individual characteristics of attention and to train their attentional abilities depending on the individuality are necessary for maintaining safe and comfortable workspace environments. We believe CDCT would be a very useful tool for those purposes.

Knowing their attentional characteristics by CDCT and realizing their improvement of attentional performance by CDCT training may raise the workers' self-monitoring ability and may stimulate their motivation to contribute the reduction of human errors. We think these aspects are important side-effects of CDCT.

For further confirmation, we have a plan to examine the relationships between the characteristics measured by CDCT and types of human errors, using subjects who have a high proneness for errors and accidents.

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