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The Performance on a Computerized Attention Assessment System between Children with and without Learning Disabilities

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Abstract

Attention is an essential function for children's learning. Cancellation tasks are one of most popular tools used for the assessment of visuospatial attention. A computerized cancellation test system was developed to investigate whether the children with or without learning disabilities (LD) would have different performances on cancellation tasks. The result showed that group differences regarding task performance are all significant and independent from types of stimulus and layout. Post hoc analysis of between-group effects showed that the control group had more correct responses ($F = 28.177$, $p < .001$), and spent less time ($F = 5.592$, $p = .021$) than the LD group.

Keywords: Computerized assessment; cancellation test; learning disabilities; visuospatial attention; selective attention.

1. Introduction

Various classification schemes have been used to define learning disabilities (LD), and they are mostly referred to have difficulties in the acquisition and use of academic skills resulted from central nervous system dysfunction (Semrud-Clikeman, 2005). Previous studies supported that comprehensive neurocognitive assessments can help determine the brain functions that are effective or with deficits for an individual's academic and daily life performance (Silver et al., 2008), and can make teachers and

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parents be aware of the individual's limitations for cognitive components to establish remediation strategies without re-addressing their inadequacies. Among the cognitive abilities, visual attention deficits have been widely documented in children with LD, and may interfere with the effectiveness of a remediation program (Copeland & Reiner, 1984; Richards, Samuels, Turnure, & Ysseldyke, 1990).

Attention is an essential function for children's learning, and it is also concerned mostly by parents and teachers for their children with learning or behavior problems (Ek et al., 2004). Visual attention is how one focuses attention on the specific targets in spite of distractions surrounded in the visual scene. Children with LD may have visual attention problems that exacerbated their management of visual materials during the academic learning. The encoding of reading materials may be hampered by inefficient processing of visual information. Research reports suggested children with LD, compared with the normal cohorts, showed impaired performance in both speed and capacity of information processing, such as slower response time and more response errors (Aman & Turbott, 1986; Casco & Prunetti, 1996; Casco, Tressoldi, & Dellantonio, 1998; Lockwood, Marcotte, & Stern, 2001; Vidyasagar & Pammer, 1999; Williams, Brannan, & Lartigue, 1987). Casco, Tressoldi, and Dellantonio (1998) found that poor reading ability is associated with higher visual error in the cancellation task, indicating the role of selective attention in reading performance. Therefore, this study would explore how is the effect of visual display organization for the visual attention function in children with or without LD.

Cancellation tests have been frequently used to examine selective attention as well as visual search abilities (Copeland & Reiner, 1984; Weintraub & Mesulam, 1988). Performance on cancellation tests gives information about how one attends to and explores the external environment (Wang, Huang, & Huang, 2006). The search path represents the visual search trajectory that an individual shifts his or her attention to locate the target. Some studies (Byrd, Touradji, Tang, & Manly, 2004; Geldmacher, Fritsch, & Riedel, 2000; Lowery, Ragland, Gur, Gur, & Moberg, 2004; Uttl & Pilkenton-Taylor, 2001) have acknowledged the utility of cancellation tasks in children with LD. Re-examination for the relationships between visual search pattern and performance parameters, as well as the visuospatial performance on target detection would provide an understanding of how children with LD attend to the reading layout.

In this study, a computer-assisted tool was used as the same computer-assisted testing procedure in Wang, Huang, and Huang (2006) but varied in the stimulus characteristics: symbols and Chinese-radical, to study whether the children with or without LD would have different performances on these two cancellation tasks, and whether the Chinese cancellation tasks would be more difficult than symbol ones for both groups to process.

2. Methods

2.1. Subjects

A total of 36 children with learning disabilities (25 boys [69.4%] and 11 girls [30.6%]) was recruited from an education project. Children with LD had been screened by local Education Bureau and gone through an evaluation protocol including WISC-III, Word recognition, reading comprehension tests, as well as class teacher observations. For this LD group, the mean age was 9.8 ±1.10 years, the mean IQ was 90.63 ±5.28, and the mean reading age was 8.34 ± 0.88.

An age-matched comparison group consisted of 42 children with no learning disabilities (NLD), 28 boys (66.7%) and 14 girls (33.3%). Participants in both groups did not have any neurological disease, physical illness, or visual or motor problems.

2.2. Apparatus and stimuli

In this study, 2 cancellation forms (symbol and Chinese-radical) with 2 test layouts (structured and random organized) were administered with computerized testing procedures by the Computer-Assisted Cancellation Test System (CACTS; Wang, Huang, & Huang, 2006). The CACTS was established on a tablet PC sized 9'×12' with a stylus pen for data input. Symbol form was reconstructed from Muslam's symbol cancellation task (1985) and consists of 52 different symbolic figures such as"☼" and "●". The Chinese form is a parallel form from the symbol cancellation and was designed by Wang et al. (2006). It composed of 26 traditional Chinese radicals which was used on the keyboard for Chinese typing, such as "日" and "工". Radicals are the basic components of Chinese characters (also called *Han characters*). Every Chinese character is composed of one or more radicals, and radicals themselves are meaningful and readable characters.

To avoid any issues caused by the complexity of language cognition, the Chinese radicals is used instead of Chinese characters as stimulus materials. The target on the symbol test was set as "☼" and the target on the Chinese-radical test was the radical "日" (meaning "sun"). Targets or distractors were presented in 24-point font. Set size was fixed at 374 items, presented at fixed locations in a 17 x 22 matrix for the structured layout. The experiment display contains 60 targets (15 targets in each quadrant) and 314 distractors scattered on the display. For the structured layout, the spacing of any two adjacent stimuli in a row or column was equivalent, but for the random layout, the spacing of any two adjacent stimuli varied. When a subject uses the stylus pen pointing onto the target shown on the screen, the CACTS automatically crossed it out with a blue cross sign and synchronously recorded the outcome data (time-stamped x- and y- coordinates) with temporal order in the database.

2.3. Procedure

Each subject was given detailed instructions and 3 practice trials until the subject felt ready for the test. Time was not limited but subjects were instructed to complete the test as fast as possible without sacrificing accuracy. When finished, subjects could press any key on the keyboard to terminate the trial. Normally, each experiment took less than 5 minutes to complete and each subject should have been able to finish all four trials within 20 minutes. Both groups were given tests by the order of symbol in structured and random layouts, then Chinese radical in structured and random layouts. The tablet was placed in front of the subject with 15 degree tilt and a distance of 20 cm from the edge of the table. Movement of head and eyes were not restricted.

2.4. Data collection and analysis

Multivariate analysis of variance (MANOVA) was used to examine the effects of group, stimulus (symbols and Chinese-radicals), and layouts (random and structured layouts) on the spatial and temporal parameters. The dependent variables were the number of correctness, task completion-time and total length of search path.

3. Results

There was no gender difference between the two groups (X^2 = .281, *df* = 1, p = .596). The descriptive data of each form for both groups were shown in Table 1. There were one between-subject factor (group) and two within-subject factors (stimulus and layout). Multivariate analysis showed that there were significant main effects of group [*F(3, 74)* = 12.532, *Wilk's lamba* = .663, $p < .001$]; stimulus [*F(3, 74)* = 10.132, *Wilk's lamba* = .709, $p < .001$], layout [*F(3, 74)* = 61.748, *Wilk's lamba* = .285, $p < .001$], and a significant interactions of stimulus by layout [*F(3, 74)* = 10.340, *Wilk's lamba* = .705, $p < .001$]. The interactions of group by stimulus, group by layout, and group by stimulus by layout were not significant. That is, group differences regarding task performance (i.e., correctness, completion time, and search path) are all significant and independent from types of stimulus and layout. Post hoc analysis of between-group effects showed that the NLD group had more correct responses (F = 28.177, $p < .001$), and spent less time (F = 5.592, p = .021) than the LD group. However, there is no difference between LD and NLD groups in the search-path length (F = 0.010, p = .921).

Table 1. Descriptive data for each form and group comparisons

	Symbol-R Mean(SD)	Symbol-S Mean(SD)	Chinese-R Mean(SD)	Chinese-S Mean(SD)	Group Mean(SE)	Between group comparison		
						Mean Square	*F*	*Sig.*
Correctness								
LD	54.3(6.3)	54.3(6.1)	53.8(6.1)	54.3(6.3)	54.1(.60)	1469.361	28.177	<.001*
NLD	58.7(2.9)	58.8(1.6)	58.1(2.1)	58.4(1.8)	58.5(.55)			
Completion time (sec.)								
LD	170.8(48.7)	197.4(59.0)	203.9(72.1)	171.7(41.7)	186.0(6.62)	35297.71	5.592	.021*
NLD	153.5(61.6)	170.1(45.9)	177.9(46.6)	156.9(40.2)	164.6(6.13)			
Search path (cm)								
LD	303.1(42.4)	412.7(103.3)	333.6(76.8)	438.5(90.3)	372.0(8.14)	94.99	0.010	.921
NLD	298.7(44.0)	395.0(114.0)	338.1(61.1)	460.4(72.0)	373.1(7.53)			

Note: R = Random, S = Structured, LD = Learning Disability, NLD = Non-Learning Disability; * $p < .05$

Group effect was examined for the test performance for post hoc analysis. The results showed that only correctness of all tests showed significance (*p's* < .001). Time was not a significant factor. LD group used more searching path on both symbol forms (random: p = .002; structured: p = .015).

The repeated one way ANOVA was used in each group to examine the test performance in terms of correctness, time, and searching path on different forms. Both groups showed equally correctness across the 4 forms (*p's* > .05). That is, Chinese or symbol form did not affect the correctness of test (See Table 2). Searching path was greater in structured than random form, and greater in Chinese form than symbol form. For NLD group, searching path from the longest to the shortest for different forms are the Chinese structured form, symbol structured form, Chinese random form, and then symbol random form with all significant differences (p's $\leq$ .005). The LD group had the same order for searching path and with significance except for the two structure forms (p = .399). Longer searching path did not associated with

longer completion time. For completion time, both group spent the longer in the Chinese random form, and the shorter in the Chinese structured and symbol random forms.

4. Discussions

The purpose of this study was to explore the performance of visuospatial attention, and comparison of search strategies for the LD and NLD groups. This study employed two different stimulus paradigms, verbal (Chinese-letter) and non-verbal (symbol) forms with two layouts (structured and random array), to examine the relationship between efficiency of visuospatial attention and search patterns. The NLD group outperformed the LD group in correctness in all of cancellation tasks. Though they used less completion time but that was not at a significant level. Whether in different forms (Chinese or symbol) or layouts (random or structured), the children in the LD group achieved around 90% of the correct score of the children in the NLD group, but they spent about 10% longer time than the children in NLD group did, for example, (54.3 vs.59.8) for correctness and (170.87 vs. 153.51) for completion time in symbol cancellation with random forms between the LD group and NLD group (See Table 1). This result revealed that the children in the LD group may have problems in visual selective attention regardless whether the stimulus is with verbal component. The LD group did not perform better in symbol than Chinese form was consisted with previous studies by Roach and Hogben (2004). Some studies suggested the attentional deficit in dyslexia was resulted from the dysfunction of magnocellular system and therefore these children may have shown difficulties in verbal content processing (Facoetti et al., 2003). Roach and Hogben (2004) compared performance on a visual search task and performance on the tasks targeted for magnocellular function in dyslexics. However, they found the dyslexics had poor performance in visual search tasks, but good in "magnocellular" tasks. The results suggested a poor attention problem during the task performance and that possibly contributes to deficiency in magnocellular functioning in the dyslexics. Working slower on the cancellation tasks in this study maybe a compensation for their visual perception problem (though not efficient), or it may represent another problem of visual attention shift (Posner & Rafal, 1987).

Table 2. Between group comparison for significant parameters: correctness and time

	Layout	*Mean Square*	*F*	*P*
Correctness				
Symbol	Random	389.09	16.91	< .001*
	Structured	392.54	20.98	< .001*
Chinese	Random	364.00	18.43	< .001*
	Structured	325.73	16.20	< .001*
Time (sec.)				
Symbol	Random	5843.16	1.86	.177
	Structured	14406.28	5.25	.025*
Chinese	Random	13021.41	3.65	.060
	Structured	4247.85	2.54	.115

*$p < .05$

The experimental result also found the visuospatial attention performance of both group was independent from the stimulus presented. There were no difference of the correctness among different stimulus forms. The LD group performed both forms with the same difficulty as indicated by lower

correct scores than the NLD group. The LD group also showed larger within-group variation than the NLD group, and it may indicate the LD group had a bigger discrepancy in visual selective attention among LD children.

With respect to the completion time of cancellation tasks, both groups spent more time in Chinese cancellation with random layout, and symbol random form and Chinese structured form were easier to complete in terms of time. The reason for that may be cognitive habit involved in search strategy. That is, stimulus types which are related to the cognitive habit will affect attention processing capacity (i.e., processing speed). When the target is a Chinese-radical stimulus, the participants (both LD and NLD groups) will recognize the stimulus as verbal words, which are usually read in a structured layout (a vertical or horizontal layout). Therefore, the participants will spend more time in Chinese-radical with the random layout than that with the structured layout. In contrast, when the participants search for a symbol stimulus, they may see symbol stimulus as a general graph, which did not involve any verbal context. The participants will employ another strategy (i.e., search for the closer target) to do target searching. As a result, participants spent less time on the target searching on the task with the random layout. This finding suggested that the processing of selective attention can be fast and efficient on a cancellation task when the participants combine their reading habits (cognitive encoding) as their visual search strategies even though different types of stimuli given in the task.

5. Conclusions

In this paper, a computer-assisted testing tool, called CACTS, was used to investigate whether children with or without LD had different task performances on cancellation task. The results showed that children with LD had poorer task correctness and their performance patterns generally were similar to the NLD group regardless of form structures. The results indicated a deficit in selective attention rather than verbal selection in the LD group.

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