Published in final edited form as:

Child Neuropsychol. 2004 September ; 10(3): 212–221. doi:10.1080/09297040490911069.

Effects of Test Order and Modality on Sustained Attention in Children With Epilepsy

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Abstract

Neurological conditions affect sustained attention, but the effects of modality and interactions with test order have not been examined. In a 2×2 (Order $\times$ Modality) design using 54 children with chronic epilepsy, performance was compared on an auditory measure (modified Seashore Rhythm Test) versus a visual measure of attention (modified Conners' Continuous Performance Test). Auditory scores were worse than visual, $F(1, 52) = 98.93$, $p < .001$, but there was no order effect or interaction ($p > .05$). Implications for assessment and intervention are discussed.

Sustained attention tests measure the capacity of an individual to maintain attention over a period of time (Lezak, 1995). The attentional ability of a person may be affected by numerous factors. Two possibilities are brain damage and fatigue, which may also interact causing a further decrease in a person's attentional ability. Lezak (1995) noted that people with brain damage might fatigue more easily and take longer to recuperate afterwards. If an individual is unusually fatigued during testing, lower attention test scores may misrepresent their true abilities. In situations where this may occur, special considerations may need to be made when deciding on the order of tests in a neuropsychological test battery.

Limited research has examined modality effects in healthy adults. In addition, two clinical populations provide some insight into the question concerning the effects of fatigue on test performance. One population consists of people who have Chronic Fatigue Syndrome (CFS). However, this population consists mostly of adults and those results may not generalize to a pediatric population. The second population consists of children with epilepsy, in whom attention deficits have been found to be rather common (Deonna, 1993; Dunn, Austin, Harezlak, & Ambrosius, 2003; Fastenau, Dunn, & Austin, 2003; Mitchell, Chavez, Lee, & Guzman, 1991; Piccirilli et al., 1994; Semrud-Clikeman & Wical, 1999; Williams, Griebel, & Dykman, 1998).

Healthy Adults

Studies comparable to the present study in a healthy population are limited. Baker, Taylor, and Leyva (1995) compared an auditory continuous performance test (CPT) to a visual CPT in a sample of healthy undergraduate students. The difficulty of the tasks was determined by the number of omissions; the participants made more errors of omission on the auditory task than

on the visual task. Thus, the results indicated that the auditory CPT was more difficult than the visual CPT (Baker et al., 1995).

Another study with healthy college students, however, suggests that visual attention might be more susceptible to distraction than is auditory attention. Using a digit span task, Turner and colleagues (Turner, Johnson, McNamara, & Engle, 1992) compared the recall of eight-digit series that were presented either visually or orally under varying levels of same-modality distraction. Distractions in the same modality were more disruptive to recall for digits presented visually compared to recall for digits presented orally (Turner et al., 1992).

Therefore, in these two studies with healthy adults, one study suggested that auditory attention is more taxing, whereas the second study suggested that visual attention is more taxing. To further investigate the effects of modality, together with the effects of fatigue (as a proxy for test order), we will review literature on attentional performances in two clinical populations that are prone to fatigue.

Adults With Chronic Fatigue Syndrome

Studies conducted on people with CFS have addressed attention in neuropsychological test batteries. The tests used to measure attention have varied in modality of presentation (auditory vs. visual) and in the length of the test (ranging from 2 min to 20 min). Conflicting results were found.

On visual attention tasks, people with CFS scored lower than healthy controls in six studies. Four of these showed clear differences (Michiels, Cluydts, & Fischler, 1998; Michiels et al., 1996; Smith et al., 1999; Vercoulen et al., 1998); two showed differences at the level of a statistical trend (Marcel, Komaroff, Fagioli, Kornish, & Albert, 1996; Ray, Phillips, & Weir, 1993). Five of the six studies finding differences between people with CFS and healthy controls used brief tests of attention (Michiels et al., 1996, 1998; Ray et al., 1993; Smith et al., 1999; Vercoulen et al., 1998), and none of the studies compared visual attention to auditory attention. In addition, most of the studies failed to report the ordering of attentional tests. Since differences found on attentional tests at the end of a battery may reflect effects of fatigue rather than modality it is difficult to determine the meaning of these results in regards to the effects of modality. Smith et al. (1999) did investigate the effects of fatigue across the length of testing by administering the attention test at the beginning and then again at the end of the test battery. Results did indicate that response rates decrease over time during testing. Two other studies showed that people with CFS scored lower than controls on visual tests of attention (Joyce, Blumenthal, & Wessely, 1996; Marshall, Forstot, Callies, Peterson, et al., 1997), but the differences were not statistically significant; this may be due to low statistical power, given the small samples in both of these studies.

On auditory attention tasks, people with CFS scored worse than healthy controls in five studies (DeLuca, Johnson, Ellis, & Natelson, 1997; Marshall et al., 1997; Michiels et al., 1996, 1998; Tiersky, Cicerone, Natelson, & DeLuca, 1998). One other study found that people with CFS had more difficulty performing an auditory attention task, but this was not statistically significant (Marshall et al., 1997). Two studies found no differences between patients and healthy controls on auditory tasks (Marcel et al., 1996; Vercoulen et al., 1998). Again, each study used brief tests of attention and none of the studies indicated the ordering of attentional tests. Although studies investigating CFS indicate a decrease in auditory attention compared to healthy controls, these results with adults may not generalize to a pediatric population. For studying the effects of order and modality on attention, a more relevant population is children with epilepsy.

Children With Epilepsy

Although some studies on children with epilepsy have failed to find strong effects on attention (McCarthy, Richman, & Yarbrough, 1995; Williams et al., 1996), other studies have shown attentional deficits are common (Deonna, 1993; Dunn et al., 2003; Fastenau et al., 2003; Mitchell et al., 1991; Piccirilli et al., 1994; Semrud-Clikeman & Wical, 1999; Williams, Griebel, et al., 1998). Although attentional deficits are ubiquitous in children with neurological conditions, the origins of these attentional deficits in epilepsy may be disorder-specific. Binnie (1993) hypothesized that ongoing subclinical interictal epileptiform discharges produce transitory cognitive impairment (TCI). There is some support for this model. During recording of abnormal EEG discharges, impaired cognitive performances have been observed for reading and arithmetic achievement (Kasteleijn-Nolst Trenité, Bakker, Binnie, Buerman, & van Raaij, 1988) and for neuropsychological skills such as abstraction/reasoning, paired associate learning, visual perception, and fine motor skills (Siebelink, Bakker, Binnie, & Kasteleijn-Nolst Trenité, 1988). As further support for the model, aggressive pharmaceutical treatment reduced EEG abnormalities, which resulted in improved cognitive and emotional-behavioral functioning (Marston, Besag, Binnie, & Fowler, 1993).

As another potential mechanism of attention deficits in pediatric epilepsy, antiepileptic drugs (AEDs) have been implicated in some of the adverse cognitive changes. However, in a review of 90 studies, Vermeulen and Aldenkamp (1995) identified the many methodological issues that place constraints on interpretations. After considering these factors they concluded, "Still, the tentative overall picture emerging from the *crème de la crème* of research on cognitive AED effects is that differences in cognitive profiles may not be *very large*" (p. 89, emphasis in original text). Others have reached a similar conclusion (Bourgeois, 1998; Dodrill, 1992; Nichols, Meador, & Loring, 1993). For most AEDs, effects on cognition appear to be minimal when used as monotherapy, when titrated slowly, and when dosed in the therapeutic range (Nichols et al., 1993; Vermeulen & Aldenkamp, 1995). A recent prospective study with children using a sensitive neuropsychological battery and a matched control group with newly diagnosed diabetes found no effects of AEDs on cognitive functioning (Williams, Bates, et al., 1998).

A preponderance of studies using children with epilepsy have found decreased attention compared to healthy controls (e.g., Baglietto et al., 2001; Massa et al., 2001; Williams, Griebel, et al., 1998). These studies have used both visual and auditory tests of attention documenting deficits in each domain. The length of the tests ranged from 2 min to 20 min. Almost all studies showed children with epilepsy to have attentional deficits (Aldenkamp et al., 2000, 2001; Baglietto et al., 2001; Culhane-Shelburne, Chapieski, Hiscock, & Glaze, 2002; Kolk, Beilmann, Tomberg, Napa, & Talvik, 2001; Massa et al., 2001; Metz-Lutz et al., 1999; Williams, Griebel, et al., 1998). An additional study showed attention deficits in children with epilepsy (Billingsley, Smith, & McAndrews, 2000), but these findings were based on postsurgical evaluation and may not generalize to children who do not require surgery.

Visual Tests of Attention

On visual attention tasks, children with epilepsy showed deficits in six studies. Five of these compared affected children to healthy controls (Aldenkamp et al., 2000; Baglietto et al., 2001; Kolk et al., 2001; Massa et al., 2001; Williams, Griebel, et al., 1998). The sixth study (Culhane-Shelburne et al., 2002) compared children with epilepsy to normative values only, but revealing a marked deficit (>2 standard deviations below the mean). The only study using a visual presentation that failed to show deficits (Croona, Kihlgren, Lundberg, Eeg-Olofsson, & Eeg-Olofsson, 1999) involved children with benign childhood epilepsy with centrotemporal spikes, a syndrome that is generally associated with less severe cognitive deficits; furthermore,

the sample was very small ($n = 17$) and may have been underpowered to detect subtle differences.

It is unclear whether or not duration of the tasks affects the outcomes. Of the six studies that showed deficits on a visual attention task, two used brief tests of visual attention (Baglietto et al., 2001; Kolk et al., 2001), and one used a longer (23-min) measure (Culhane-Shelburne et al., 2002). In the other three studies, the duration of the tests could not be ascertained (Aldenkamp et al., 2000; Massa et al., 2001; Williams, Griebel, et al., 1998).

Auditory Tests of Attention

Children with epilepsy scored lower than controls on auditory attention tasks in two studies (Aldenkamp et al., 2000; Metz-Lutz et al., 1999). One of the studies used a computerized simple reaction time test in which the child had to respond to stimuli in the auditory modality (Aldenkamp et al., 2000). The other study measured auditory attention with a dichotic listening paradigm. Attention was impaired independent of the lateralization of the seizure focus (Metz-Lutz et al., 1999). The length of the tests used in both studies was indeterminable based on the information provided.

Comparisons Between Modalities

Of the studies reviewed, most measured attention in only one modality, thereby precluding comparisons between modalities. In the two studies that did test attention in both the visual and auditory modalities, there was no comparison between the modalities (Aldenkamp et al., 2000; Massa et al., 2001). Therefore, no conclusions can be drawn about differences between modalities, and potential interactions between modality and test order on attention have not been examined. It is evident from this review that more research is needed to investigate the effects of test order and modality on attentional abilities, especially in children with neurological disorders.

In a pilot study, Taylor-Cooke and Fastenau (2001) attempted to address these issues in children with epilepsy. In a $2 \times 2 \times 3$ (Order $\times$ Modality $\times$ Clinical Status) factorial design, they compared 20 children with chronic epilepsy (mean duration of 89 months), 25 children with recent-onset epilepsy (mean duration of 28 months) and 12 healthy controls on attention tests that were presented in the visual modality (Conners' Continuous Performance Task, or "CPT;" Conners, 1995) or in the auditory modality (Attentional Capacity Test, or "ACT;" Weber, 1988). Order of the two tests was determined by random assignment for each child.

There was a 3-way interaction: Results indicated worse attentional scores on the test administered second, but this was observed only in the chronic epilepsy subgroup and only on the CPT. However, there were two potentially confounding factors in that experiment. First, the two attentional tests lacked equivalence on three critical dimensions (administration time, extent of examiner interaction, and the nature of the dependent variables). Second, the two attention tests were administered back-to-back, which is not characteristic of neuropsychological test batteries.

The present study was conducted to correct for the confounding variables in Taylor-Cooke and Fastenau's (2001) pilot study. The following hypotheses were addressed: (1) The test administered last would produce worse scores than the test administered first. (2) There would be an interaction between order and modality, but the direction (i.e., which modality would be most vulnerable to order effects) was not specified.

METHOD

Participants

Children with chronic epilepsy ($n = 62$) were tested at their 12-month follow-up for an ongoing study of adaptation to childhood epilepsy. To be included in the parent study, children were required to be prescribed antiepileptic medications with good seizure control (i.e., no medically refractory seizure condition). Also, children with a diagnosis of mental retardation were excluded. The children were assigned to one of two groups on an alternating basis as they were scheduled. All children completed the study except for five who were unable to understand the directions related to the Seashore Rhythm Test (SRT) and three others who were inadvertently administered the full length Conners' CPT. Out of the children completing the study, 25 children (8 male, 17 female) were placed in the group receiving the SRT first, and 29 (13 male, 16 female) were placed in the group receiving the SRT last. There were no differences between groups on age, gender, or IQ (Kaufman Brief Intelligence Test; Kaufman & Kaufman, 1983). In the absence of a composite index of seizure severity, the two groups were compared on several seizure variables. There was no difference between groups on parent's satisfaction with child's seizure control (0 = Not at All, 7 = Very Satisfied), percent of each group on polytherapy, or percent of each group having multiple seizure types. With regard to seizure frequency, more variation was found between groups; however, non-parametric analyses, which are not affected by outliers, showed no differences. In addition, the two groups appeared to show similar distributions across primary seizure type, side of seizure focus, or region of seizure focus on EEG (see Table 1).

Materials

The Conners' Continuous Performance Task (CPT; Conners, 1995) and the Seashore Rhythm Test (SRT) were chosen to represent the visual and auditory modalities, respectively. In order to make the tests more comparable to each other the SRT was doubled in length, and the CPT was revised to run for the same length of time. Each test was then approximately 9.5 min in length.

The answer sheet for the SRT was copied on two sides of colored paper to prevent the children from figuring out that it was the same test only doubled. When dubbing the tape, the beginning of the tape was deleted for the second part, again to prevent the children from recognizing that Part II was the same as Part I. Instructions for the SRT were also revised to explain to the children to turn over the answer sheet for Part II. The CPT directions were given according to standardized procedures.

Percent omissions were analyzed for both the CPT-R and the SRT-R. On the CPT-R, omissions were computed based on the number of targets missed. On the SRT-R, all errors (i.e., not recording a response or, more often, recording an incorrect response) were counted as omissions. Past research with the SRT has shown that incorrect responses on this test are associated with inattention more typically than with deficits in auditory processing (Lezak, 1995).

Seven subtests of the Woodcock-Johnson Psycho-educational Battery – Revised (WJ-R; Woodcock & Johnson, 1989) were administered to each child in addition to the attention tests. This test was administered according to standardized procedures.

Design and Procedure

Hypotheses were tested using a 2×2 (Order $\times$ Modality) mixed design, with one between-subject (Order) and one within-subject (Modality) variable. Participants were assigned to one of two groups. The first group received the revised SRT (SRT-R) first followed by the WJ-

R, followed by the revised CPT (CPT-R). The second group received the same tests except the order of the two attentional tests was reversed. Total testing time ran approximately 2 hr. Each child was individually tested between the hours of 9 am and 5 pm. Trained psychometrists administered all tests on an individual basis.

RESULTS

Table 1 and Figure 1 present the mean performance for each group on both attentional measures. Analyses indicated a significant difference in modality, $F(1, 52) = 98.93, p < .001$, with a greater proportion of errors on the SRT-R than on the CPT-R. There was no order effect, $F(1, 52) = 0.26, p > .05$, nor was there an interaction, $F(1, 52) = 0.11, p > .05$.

Post hoc analysis was conducted to compare the performance of children in each group on the SRT-R who were on no therapy, monotherapy, or polytherapy. A 2×3 (Group $\times$ Medication) ANOVA indicated no effect of medication status on SRT-R omissions, $F(2, 44) = 0.10, p > .10$, and no interaction, $F(2, 44) = 0.46, p > .10$.

An additional post hoc analysis repeated the 2×2 (Order $\times$ Modality) ANOVA but controlled for psychomotor speed using a measure that was independent of the attention tasks (Grooved Pegboard). In a 2×2 (Order $\times$ Modality) ANCOVA, covarying on Grooved Pegboard time to completion with the dominant/preferred hand, the covariate was not significant, and the results remained unchanged. That is, there was an effect for modality, $F(1, 52) = 13.35, p = .001$, but no effect for order, $F(1, 52) = 0.24, p > .05$, and no interaction, $F(1, 52) = 0.16, p > .05$. Although Pegboard scores were obtained 1 year prior to the present study (at Baseline phase in a broader 2-year longitudinal study), a paired t -test on a group of children ($n = 26$, representative of those in the present study) showed no change in Pegboard dominant-hand times over the 2-year duration of the longitudinal study, $t(25) = 1.29, p > .05$, thereby justifying the use of these Pegboard scores as a covariate in the present study.

DISCUSSION

These results suggest that the order of attentional tests in a neuropsychological battery does not affect the scores when the attention tests are separated in the test battery. This finding fails to support Hypothesis 1. Placing attentional tests toward the end of a battery appears to have no effect on scores, especially within a 2-hr block of testing.

The second hypothesis was supported. Differences were observed between modalities; scores were lower on the SRT-R (auditory test) than on the CPT-R (visual test). This result suggests that neurologically compromised children may be more inattentive to information presented in the auditory modality. Post hoc analyses suggest that the lower SRT-R score cannot be attributed to the effects of medications or to the effects of psychomotor speed.

In the current experiment, the tests were equated on length, on examiner interaction, and on the nature of score analyzed (i.e., percent omissions). However, the SRT-R and CPT-R may not be equal still. The instructions given for the CPT-R are rather simple and easily understood by children, whereas the instructions for the SRT-R may be confusing for some children. Most of the children who did not complete the SRT-R did so because either they did not understand directions or they were confused about where the tone sequences were separated and which sequences they were comparing. Given these difficulties with the SRT-R, it is possible that this study also contained a confounding variable, which may have affected the results. Children who had difficulties understanding the SRT-R ($n = 5$) were excluded from the study to help control for the impact of this confound on the findings; however, other children with more subtle receptive language deficits might have been retained and lowered the mean for the auditory condition.

The tests also differed in stimulus presentation in subtle ways that might have yielded different raw scores. For instance, the presentation of tone sequences contains a small component of working memory in which the child must remember one tone sequence while listening to the next before responding; the presentation of the stimuli in the CPT–R, on the other hand, requires the child to register the stimulus only very briefly before responding. The subtle differences in the tests make it difficult to identify specific characteristics of both tests that might be responsible for the current results.

As another possibility, the SRT–R was designed to measure auditory discrimination of tonal rhythms, and it was once believed to measure the integrity of right temporal lobe functioning. The test has since been shown to be neither lateralizing nor localizing in nature in adults (Reitan & Wolfson, 1989; Sherer, Parsons, Nixon, & Adams, 1991) or in children (Dennis & Hopyan, 2001). Instead, this test corresponds with tests that are widely accepted as measures of attention (Waterloo, Omdal, Mellgren, & Husby, 1997) and is generally regarded to be a measure of general cerebral functioning, and of attention in particular (Lezak, 1995). The potential impact of temporal lobe foci in the present sample is further reduced by the relatively small proportions of children with temporal lobe foci in each group (14–16%). Therefore, it seems unlikely that rhythm discrimination is responsible for the lower scores on the SRT in the present study.

As yet another potential difference, the two tests also differ on response demands. The CPT–R requires the child to press a bar in response to the stimuli, whereas the SRT–R requires the child to write a letter as a response. A possibility is that psychomotor slowing could account for some of the difference between scores on the two attention tests. This possibility seems unlikely based on our post hoc analysis.

Finally, most children were on only one antiepileptic drug. As described in the literature review, recent reviews of antiepileptic drugs concluded that antiepileptic drugs, when used in monotherapy, appear to have minimal effects on cognitive functioning. In addition, post hoc analyses comparing children on no therapy, monotherapy and polytherapy for each group on the SRT–R found no differences. This suggests that, in this population, the number of AEDs each child was currently taking did not affect their scores on the auditory attention task. These results further indicate that the lower SRT–R scores cannot be accounted for by children on polytherapy reducing the overall means for the group.

Although these confounds cannot be ruled out with certainty, the present results suggest that attention may be taxed more by auditory information than by visual information for children who have epilepsy, and possibly for other children with neurologically based attentional deficits. This finding has implications for the practice of pediatric neuropsychology in assessment, educational planning and therapy. With regard to assessment, visual continuous performance tasks appear to be very popular; however, auditory tests of attention may be more sensitive to attentional deficits in children with epilepsy. With regard to educational intervention, these findings suggest that children with epilepsy may be at greater risk for missing important information discussed in the classroom; if such deficits were confirmed for an individual child on a neuropsychological exam, special accommodations (e.g., tape recording lectures) might be a consideration to help prevent students from missing critical information. With regard to psychotherapy, children with epilepsy who show these auditory attention deficits on a neuropsychological exam may warrant special considerations. Deficits in auditory attention could possibly make it difficult for these children to understand and retain information that they process with the therapist. Writing down important points from therapy sessions could help to prevent that information from being missed.

The effects of modality on attention should be examined further. In future studies the visual and auditory tests used could be even more comparable in instructions and stimulus

presentation. Measures should be equated on several dimensions such as instructions (e.g., same instructions of equal length and ease of comprehension), types of stimuli (e.g., using only letters as the stimuli), and the mode of responding to the stimuli (e.g., key-pressing to all letters except one). In addition, differences between modalities could be investigated in healthy children; there may be a tendency for children to perform worse on tests in the auditory modality, irrespective of neurological disease.

Acknowledgments

This project was directly supported by an IUPUI UROP grant to Patricia Taylor-Cooke. The chronic sample was recruited from a study funded by NIH/NINR #NR04536 to Joan K. Austin (PI), David W. Dunn, Philip S. Fastenau, and Gertrude Huster. The authors are indebted to Dr. Kathy E. Johnson for her comments on an earlier draft.

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Fig. 1.
Mean percent errors (± 1 SD), by test and by experimental group.

Table 1

Demographic Data and Test Scores by Group

Measure	SRT-R First (<i>n</i> = 25)		SRT-R Second (<i>n</i> = 29)		<i>t</i> , <i>U</i> or χ^2	<i>p</i>
	M	SD	M	SD		
Age (years)	13.1	1.8	12.8	2.1	.43	>.10
K-BIT Composite IQ	93.8	16.4	89.9	14.8	.90	>.10
Female (%) ^b	68.0		55.2		.93	>.10
Left handed (%) ^b	8.0		27.6			.10
Caucasian/Non-Hispanic (%) ^b	88.0		79.3		1.40	>.10
Epilepsy duration (months)	85.2	40.8	82.8	39.6	.14	>.10
Seizure frequency (per month) ^a	0.0	59.6	0.0	3.3	293.00	>.10
Parent's satisfaction with child's seizure control	5.8	1.8	6.4	1.4	-1.22	>.10
% on Polytherapy ^b	16.0		17.2			>.10
% with multiple seizure types ^b	75.0		66.7			>.10
Primary seizure type (% of Group) ^c						— ^c
Generalized tonic-clonic	24.0		17.2			
Absence	16.0		10.3			
Simple partial	0.0		6.9			
Complex partial	24.0		27.6			
Simple partial w/secondary generalization	8.0		0.0			
Complex partial w/secondary generalization	20.0		17.2			
Missing or unclassified	8.0		20.6			
Side of seizure focus on EEG(% of Group) ^c						
L > R	16.0		6.9			
L = R	36.0		27.6			
L < R	12.0		6.9			
No spike-wave activity detected	36.0		58.6			
Region of seizure focus on EEG(% of Group) ^c						
Frontal	4.0		0.0			
Temporal	16.0		13.8			
Central	12.0		13.8			
Parietal or occipital	8.0		0.0			

Measure	SRT-R First (<i>n</i> = 25)		SRT-R Second (<i>n</i> = 29)		<i>t</i> , <i>U</i> or χ^2	<i>p</i>
	M	SD	M	SD		
Generalized	24.0		10.3			
Independent multifocal	0.0		3.4			
No spike-wave activity detected	36.0		58.6			
<i>Test scores</i>						
SRT-R (% Omissions)	26.8	16.6	28.9	16.6	0.22	>.10
CPT-R (% Omissions)	5.4	5.6	6.0	5.9	0.89	>.10

Note. CPT-R = 9.5-min administration of Conners' Continuous Performance Test; SRT-R = 9.5-min administration of Seashore Rhythm Test (double administration).

^aDue to skewed distributions, median is reported instead of mean; Mann-Whitney-*U* was used to compare groups.
^bPearson χ^2 was used to compare groups. Fisher's Exact Test used to compare groups when low expected values in one or more cells.
^cUnable to compute χ^2 due to low expected values in multiple cells.