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# **Normative Evaluation of a Letter Cancellation Instrument for the Assessment of Sustained Attention: A Construct Validation Study**

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## **ABSTRACT**

Cancellation tests are simple instruments that have traditionally been used to study sustained attention. Common formats follow a test pattern in which rows of letters symbols or numbers are randomly interspersed with designated targets. Test participants are generally asked to identify targets while ignoring similar non-target distracter items. In the current study we present normative data on a new cancellation instrument developed at SDSU. We present guidelines for administration, as well as normative data on omission errors, commission errors, mean target hit rates, processing speed performance, and test-retest reliability for 102 undergraduate participants in the 18-25 year old age range. Statistical analysis suggests that the NIMH-SDSU Letter Cancellation Protocol has high test-retest reliability, but is also susceptible to practice effects when subsequent administrations occur within 5 weeks.

## **INTRODUCTION**

One of the most pervasive and poorly understood behavioral disturbances encountered in neuropsychiatric and educational contexts is the symptom of impaired attention (Mirsky, Anthony, Duncan, Ahearn, & Kellam, 1991; Mirsky, Bryand, & Tatman, 1995). All humans experience lapses in attention, and research on attention in both normal and disordered states has exploded over the last three decades. Evidence is rapidly accumulating that suggests that the attention system in humans consists of a multi-component network that requires the coordinated action of several cerebral areas including the frontal lobes, basal ganglia, corpus callosum, and cerebellum (Fan, McCandliss, Sommer, Raz, & Posner, 2002; Giedd, Blumenthal, Molloy, & Castellanos, 2001). Cognitive processes carried out by the attentional network in humans includes spatial orienting to stimuli, maintaining an aroused and alert mental state, disengaging from and shifting between competing stimuli in a complex environment, and sustaining focus in mental operations (Mirsky, 1991; Posner & Peterson, 1990).

Given that disturbances of attention are a prominent symptom of a wide range of clinical disorders (e.g. epilepsy, seizure disorders, schizophrenia, closed head injury, etc.) neuropsychologists have focused significant effort on the development of test batteries to assess normal and disordered attention states (Duncan & Mirsky, 2001; Katz, Wood, Goldstein, Auchenbach, & Geckle, 1998; Lovejoy et al., 1999; Mirsky, 1991; Mirsky & Duncan, 2001). Attempts to develop neuropsychological batteries for the assessment of attention that have both high sensitivity and adequate specificity have been complicated by the varieties of tasks carried out by the attention system and by the differential impairment of attention processes in various clinical disorders (Lovejoy et al., 1999; Mirsky & Duncan, 2001).

One important method of assessing the ability to sustain and focus attention, which has seen wide inclusion as a component in neuropsychological batteries, is the target cancellation test. Clinical and experimental studies of attention have used cancellation tests for well over 100 years, and the procedures have been noted to require sustained attention, rapid visual scanning and motor activation, and rapid inhibition of responses (Lezak, 1995).

Cancellation tests generally consist of simple pencil and paper tests in which target stimuli (usually some designated type of letter, symbol, or numeral) are randomly scattered among similar non-target distracters. Participants' performance may be scored in a variety of domains including analyzing correct responses to targets, type and pattern of error responses, and time to task completion. Stimulus conditions are often varied by changing the frequency or appearance of the targets, which subsequently produces an increase or decrease in the attentional load required to successfully complete the task. Poor performance may reflect a variety of neuropsychological impairments including acute focal brain injury, general response slowing due to diffuse brain damage, deficits of response shifting, deficits impairing smooth motor performance, and impairments leading to bilateral or unilateral inattention (Lezak, 1995).

The current study presents normative data on 102 undergraduate participants collected at South Dakota State University using a new cancellation test. The instrument consists of four conditions in which target items are varied to manipulate the difficulty (i.e. the attentional demands) of the task.

The goals of the study were: 1) to establishing normative data for the test instrument such that it can be used in clinical practice; 2) to re-test a subset of participants in order to examine test reliability, and to assess the potential for practice effects (a common clinical concern).

## METHODS & MATERIALS

### *Description of the Test Instrument*

The NIMH-SDSU Letter Cancellation Protocol was developed based on an instrument adapted by Mirsky et al. (1991) from original work by Talland (1965). It consists of four conditions in which participants are required to search for specific target items embedded in an array of similar items (Figure 1).

Experiment 1 - Condition 1 with target items highlighted.

u r s i p i o x o r d a q s i e o u k k s a x w k e 10  
 s e r u n k r a s x b w b a b x f v q b r t d k e 20  
 c b a h x u i w h x p f h i k b k z g t w i v p a a 30  
 u u a g r i i c l l h h k l g w e q j r n q c q u j 40

Experiment 1 - Condition 2 with target items highlighted.

O a j l P A x n f j q w z l r f s w o o f y v G n e x b y 5  
 Y S U d c a x q T j c g q g o z x g e m t w z v n d X r B 5  
 Z c n s h e y w o c r Z Q j m x s g i v v f x f f z w c 5  
 q X c f j h Y E m D d f O c j j m R z R a g s c s y G U 5

Experiment 1 - Condition 3 with target items highlighted.

x z m y z l a w v t a u m k s m e w r b p 15  
 x a g p n a b z o n u x b l q o i j l l k r 14  
 r v t n i o r c y q j y n s q v g i x m p e 15  
 o t r p l l g y l a v e w e s y n y v n z n p 15

Figure 1. Conditions 1-3 of the NIMH-SDSU Letter Cancellation Protocol.

In developing the test, careful attention was paid to the selection of font type and size, specifically so that capital letters could easily be distinguished from lower case letters, and spacing between letters was easily identified. Several pilot studies were conducted until an optimum font was identified. In addition, the distribution of target items was carefully counterbalanced between conditions, as well as bilaterally counterbalanced (all problems noted with the original Mirsky et al. instrument).

*Test Administration Procedure*

In Condition 1 (Capital Letters Condition), participants are asked to move across the lines from left to right marking slashes through all capital letters as rapidly as possible. Each participant is allowed 60 seconds to complete this condition, and the condition is administered twice in succession (trials 1 & 2).

In Condition 2 (Spaces Condition) participants are asked to move across the lines from left to right looking for double spaces that periodically occur between letters. Each participant is instructed to mark a slash through the letter immediately before and immediately after the double space. As before, each participant is allowed 60 seconds to complete this condition, and the condition is administered twice in succession (trials 3 & 4).

In Condition 3 (Dual Condition) participants are asked to complete both tasks (e.g. marking both capital letters and the letters before and after the double spaces). As before, each participant is allowed 60 seconds to complete this condition, and the condition is administered twice in succession (trials 5 & 6).

In Condition 4 (Processing Speed Condition) participants are asked to again complete both tasks (e.g. marking both capital letters and the letters before and after the double spaces). However, this time they are asked to complete an entire page of letters with no time limit and only one trial is administered (trial 7).

The purpose of the testing procedure described above is to incrementally increase the difficulty of target identification and measure the participant's response as the task becomes progressively more difficult. In individuals who experience problems sustaining attention, the increase in task demand is generally associated with a decrease in target hit rate and an increase in errors of target identification. In addition, the distribution of target items between conditions and the bilateral counterbalancing within conditions is designed to allow for assessments of visual field defects and spatial neglect syndromes. Finally, condition 4 was designed as a stand-alone measure of visual motor processing speed over a sustained period of time. The entire procedure averages approximately 14 minutes in administration time. We feel that the stepwise increase in attentional demand, short administration time, and multiple neuropsychological domains assessed by this instrument are significant procedural strengths that make it a unique and valuable tool for the study of attention.

## PROCEDURE

One hundred and two volunteer participants were recruited from undergraduate psychology classes using advertisements posted on the Internet. Participants were compensated where appropriate with course extra credit. Inclusion criteria for the study required that participants be between 18 and 25 years of age, had received adequate sleep during the prior 24-hour period, and had no previous history of attention or neurological disorders. In addition, participants were screened for current use of stimulant medication, anti-anxiety or anti-depressant medications, or the use of illegal drugs during the previous year. All participants were tested individually by appointment in a quiet room; demographic characteristics for the sample are presented in Table 1.

	N	Minimum	Maximum	Mean	Std. Deviation
Age	102	18.01	25.02	19.15	1.15
Education	102	13	19	13.37	.845
Males	22				
Females	80				

**Table 1.** Demographic Characteristics for Experiment 1.

To assess the reliability of the test and the potential for practice effects a random subset of 21 individuals were asked to return for a second testing session. Administration methods and procedures during the second testing session were identical to those in the first session.

## SCORING & RESULTS

All data was analyzed using SPSS 12.0 for Windows. Initially each test condition was scored for errors of omission (failure to correctly mark a target item), errors of commission (incorrectly marking a non-target item), and total number of correct responses (hits to target items). Total number of omission errors and total number of commission errors were obtained by summing across conditions 1-3 (trials 1-6). Total number of correct hits to target items was also summed across conditions 1-3 (trials 1-6). Omission errors, commission errors, and total number of correct hits to target items for condition 4 (trial 7) was calculated separately. In addition, time to completion (in seconds) for condition 4, was calculated separately from conditions 1-3. Means and standard deviations for each variable are presented in Table 2.

	N	Range	Minimum	Maximum	Mean	Std. Deviation
Total Time (in Minutes)	102	14.00	10.00	24.00	14.19	2.51
Total Hits	102	359.00	298.00	657.00	452.32	66.62
Mean Hit Rate (total hits / 6)	102	59.83	49.67	109.50	75.20	11.32
Total Number of Omissions	102	170.00	.00	170.00	16.57	20.48
Total Number of Commissions	102	19.00	.00	19.00	2.15	3.48
Time for Condition 4 (in Seconds)	102	209.00	159.00	368.00	239.10	35.49
Total Hits for Condition 4	102	43.00	267.00	310.00	301.65	8.11
% Correct for Condition 4	102	13.87	86.13	100.00	97.30	2.61
Total Omissions for Condition 4	102	43.00	.00	43.00	8.33	8.11
Total Commissions for Condition 4	102	10.00	.00	10.00	1.19	1.62

**Table 2.** Descriptive Data for Experiment 1.

To assess the reliability of the instrument, we randomly asked twenty one (21) participants (20.5 %) to return for a second testing session and conducted a test-retest reliability analysis. Correlations using Pearson's method were conducted on the entire retest sample as well as on groups broken down by length of retest interval. Twenty-one participants returned between one and five weeks after initial testing. Results suggested that all measures with the exception of commission errors in trial 7 (processing speed condition) showed high test-retest reliability (Table 3).

Source	First Testing		Second Testing		
	Mean	SD	Mean	SD	r
Total Score	451.85	69.84	489.42	59.64	0.850 *
Total Mean	75.07	11.85	81.57	9.94	0.840 *
Total Omissions Trials 1-6	12.09	7.93	7.95	6.47	0.658 *
Total Commissions Trials 1-6	1.66	2.63	1.28	2.00	0.692 *
Total Time for Trial 7	245.95	43.31	216.04	28.26	0.857 *
Total Score for Trial 7	303.09	4.93	305.71	2.66	0.750 *
Total Omissions for Trial 7	6.90	4.93	4.28	2.66	0.750 *
Total Commissions for Trial 7	1.14	1.31	0.95	1.35	0.172

**Table 3.** Correlations between Test-Retest Measurements for Experiment 1.

To assess the question of practice effects, we conducted an Analysis of Variance between scores obtained during the first testing session and the retest session. Inspection of the data revealed that the total score (hit rate) was significantly higher for the combined sample at retest than initially,  $F(1, 20) = 21.86$ ,  $p < .01$  (Table 4). This finding indicates that participants' performance increased significantly at retest and suggests a practice effect.

Source	Sum of Squares	Df	Mean Square	F
Test-Retest	14821.929	1, 20	14821.929	21.86 *

**Table 4.** Analysis of Variance Results for Experiment 1.

## DISCUSSION

This study was designed to gather normative data on a new neuropsychological assessment tool for the measurement of sustained attention and psychomotor processing speed. We were specifically interested in establishing normative data for the test instrument such that it can be used in clinical practice, and in re-testing a subset of participants in order to examine test reliability and assess the potential for practice effects.

Results from this study suggest that the test does have high internal reliability but is susceptible to practice effects, and thus should not be used with the same individual without a significant intervening interval.

### *Limitations*

Several important limitations in this study should be noted. In particular, the range of time between test and retest was more variable than we would have liked, and we believe that several samples spanning a broader temporal interval should be obtained to definitively establish guidelines for retesting. In addition, given the well known age-

related changes in visual motor processing speed, the application of the normative data in this study should be restricted only to individuals in the 18-25 year old age range.

### *Summary*

In summary, The NIMH-SDSU Letter Cancellation Test is an effective neuropsychological tool that is easy to administer, takes less than 15 minutes for a participant to complete, and yields measures of inattentiveness (omissions), impulsivity or failure of inhibition (commissions), visual-motor processing speed, and may also be used to assess visual field defects and spatial neglect syndromes. The normative data and guidelines for use gathered in this study should prove useful to clinicians and researchers interested in using the instrument for the assessment of sustained attention.

Plans for future research include the assessment of different age ranges to establish a larger normative data base, further studies to establish the length of time necessary before the instrument can be re-administered, and the inclusion of clinical populations to assess the discriminative validity of the instrument.

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