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Construct Validity of the Continuous Visual Memory Test

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The construct validity of the Continuous Visual Memory Test (CVMT), a new measure of visual recognition memory was evaluated based on the performance of 92 healthy, normal adults. A series of factor analyses were conducted utilizing marker variables for verbal memory, visual memory, attention and concentration, and verbal and visual/nonverbal intellectual functions. CVMT acquisition scores were associated with verbal and visual/nonverbal intellectual factors as well as with attentional ability. The CVMT delayed recognition score was shown to be a factorially "pure" measure of visual memory.

The field of clinical neuropsychology has seen a recent increase in the development of memory assessment procedures. The increased availability of memory tests is directly related to the central importance of memory functioning in such widespread clinical conditions as closed head trauma, Alzheimer-type dementia, and cerebrovascular disease. Attesting to the proliferation of memo-

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ry assessment procedures, several test reviews have been published recently (Cunningham, 1986; Loring & Papanicolaou, 1987; Mayes, 1986), and new assessment procedures have appeared since those reviews were conducted. Among the newly developed memory assessment measures are the California Verbal Learning Test (CVLT; Delis, Kramer, Kaplan, & Ober, 1987), the Wechsler Memory Scale - Revised (WMS-R; Wechsler, 1987), and the Continuous Visual Memory Test (CVMT; Trahan & Larrabee, 1988).

Critical evaluations of procedures used to assess memory have highlighted the need for a component process approach, whereby multiple measures are utilized to evaluate attention/concentration, immediate memory, verbal and visual learning and retention, and remote recall (Cunningham, 1986; Erickson & Scott, 1977; Larrabee, 1987; Loring & Papanicolaou, 1987; Mayes, 1986). Cunningham (1986) and Larrabee, Kane, Schuck, and Francis (1985) have advocated using factor analysis to establish the dimensionality and construct validity of memory testing procedures. Indeed, factor analysis was employed in the development of the CVLT (Delis, Freeland, Kramer, & Kaplan, 1988), the WMS-R (Wechsler, 1987), and the CVMT (Trahan & Larrabee, 1988).

The present study was designed to evaluate the factorial validity of the CVMT. This test, which is described in detail in the Method section, uses a visual recognition procedure to measure acquisition of visual memory discriminations and a delayed multiple choice recognition memory procedure. Previous research has demonstrated the sensitivity of the test to unilateral cerebrovascular disease and to memory impairment in severe closed head trauma, amnestic syndrome, and Alzheimer-type dementia (Trahan & Larrabee, 1986, 1988; Trahan, Larrabee & Quintana, 1990). The present study included marker variables in an attempt to delineate separate dimensions of visual memory, verbal memory, attention/concentration, and verbal and visual/nonverbal intelligence (cf., Larrabee et al., 1985).

Previous factor analytic studies using verbal memory procedures have revealed little change in the pattern of loadings when verbal learning and acquisition scores are analyzed separately from delayed verbal recall scores (Larrabee et al., 1985; Larrabee & Levin, 1984). However, such similarities in factor structure have not always been found when using visual memory procedures. Larrabee et al. (1985) found that immediate Wechsler Memory Scale (WMS) Visual Reproduction (VR) scores were more closely associated with Wechsler Adult Intelligence Scale (WAIS) Block Design and Object Assembly performance. On the other hand, 1/2-h delayed WMS VR scores were more closely associated with performance on other memory tests than with WAIS nonverbal cognitive measures. Additionally, other research suggests that the use of delayed recall procedures may mitigate the confounding effects of verbal labeling on visual memory test performance (De Renzi & Spinnler, 1966; Ellis & Daniel, 1971). For these reasons CVMT acquisition and delayed scores were analyzed separately.

Variables chosen as markers for visual memory were the immediate and delayed reproduction trials of the WMS VR Subtest (Russell, 1975; Trahan, Quintana, Goethe, & Willingham, 1988). Marker variables for verbal learning and memory included the Consistent Long-Term Retrieval (CLTR) score for the 12 acquisition trials of the Verbal Selective Reminding Test (VSRT; Buschke, 1973; Larrabee, Trahan, Curtiss, & Levin, 1988; Levin, Benton, & Grossman, 1982), and the Total Score for the three acquisition trials of the Expanded Paired Associate Test (EPAT; Trahan, Larrabee, Quintana, Goethe, & Willingham, 1989). WAIS-R Information and the Vocabulary Test from the Shipley Institute of Living Scale (Zachary, 1986) were chosen as marker variables for verbal intelligence, whereas WAIS-R Picture Completion and Block Design were chosen as marker variables for visual/nonverbal intelligence. These measures were selected because of their high correlation with more global indices of intelligence such as the WAIS-R Verbal and Performance IQs. Two variables were chosen to assess attention and concentration: (a) WAIS-R Digit Span, and (b) a timed vigilance test requiring the subject to circle the number "5" each time it appeared in a series of random numbers.

METHOD

Subjects

The subjects were 42 men and 50 women volunteers recruited from the Galveston and San Antonio, Texas communities. Subjects were not paid for their participation. Subjects ranged in age from 18 to 61 years (Mean = 32.16; *SD* = 12.30). Subject's level of education ranged from 8 to 20 years (Mean = 13.54; *SD* = 2.26).

Subjects were screened prior to testing to exclude those with a history of neurological disease or major psychiatric illness. Screening was performed by means of a clinical interview with the subject. We excluded those with a known history of cerebrovascular disease or stroke, transient ischemic attack, head trauma with loss of consciousness, seizures, tumors or infectious disease involving the central nervous system, alcohol abuse, drug abuse, psychosis, or major depression. Subjects were not excluded from the study due to the presence of stroke risk factors (i.e., hypertension, diabetes, heart disease, or smoking) unless there was demonstrable evidence of an actual cerebrovascular event. All subjects were healthy, nonhospitalized individuals with no evidence of mental deficiency. The latter decision was made on the basis of past academic and occupational attainment. The majority of subjects (90 of 92) had at least a high school education. The other subjects had histories of occupational achievement that would reasonably preclude significant mental deficiency.

Materials

Continuous Visual Memory Test (CVMT). The CVMT (Trahan & Larrabee, 1988) is comprised of 112 complex, ambiguous drawings (e.g., 12-point polygons, etc.) and irregular nonsense figures. The drawings are printed on 5 × 8 inch white cards and organized in 7 blocks of 16 stimuli. The drawings are presented successively to the subject and exposed for 2 s each. Stimuli in the first block by definition are new and different and represent the input stimuli. Seven of these drawings appear once in each of the remaining six blocks and are "old" drawings whenever they reappear. The other nine drawings in each block are entirely new stimuli that never reappear in the task. However, seven of the "new" drawings in each of the last six blocks have similar stimulus characteristics (e.g., 12-point polygons, 7-point polygons, etc.) as the "old" drawings, one from each category. These drawings are perceptually quite similar to the corresponding "old" drawings. The other two "new" stimuli in each block belong to other stimulus classes. Because no "old" stimuli are presented in the first block, analysis of performance is based on responses given in the last six blocks, which together contain 42 "old" and 54 "new" stimuli. Scores employed in the current study included *d* prime (*d'*), a signal detection index of memory sensitivity in the acquisition phase, and a 30-min delayed multiple choice recognition memory score that reflects the subject's ability to detect each recurring stimulus from the six perceptually similar, nonrecurring stimuli within each stimulus category.

Verbal Selective Reminding Test (VSRT). The VSRT was administered and scored following the format described by Buschke (1973). The specific VSRT form utilized in this study is depicted in Levin et al. (1982) and detailed in Larrabee et al. (1988). This test is comprised of 12 unrelated words: bowl, passion, dawn, judgment, grant, bee, plane, county, choice, seed, wool, and meal. The subject hears the entire list on the first trial only. Thereafter, the examiner repeats only those words not recalled by the subject on the immediately preceding trial. Yet, the subject is still asked to give all the words from the list on each trial.

The VSRT score used in the present analysis was CLTR. A word that is recalled consecutively on two trials, then recalled consistently, without reminding, until termination of the learning trials is considered to be in CLTR. The CLTR score for the test represents the sum of the number of trials in CLTR for each of the 12 individual words.

Expanded Paired Associate Test (EPAT). The EPAT is a modification of the original WMS Form I Paired Associate Learning Test (Trahan et al., 1989). Four additional "hard" paired associates have been added: "lampshade-sidewalk," "crossroad-pillow," "lawnmower-envelope," and "automobile-scissors." Administration followed the same three-trial procedure described in the

WMS manual, with the addition of a 1/2-h delayed paired associate recall trial. The number of word pairs acquired, summed across the three acquisition trials, was employed in the current study.

Visual Reproduction Subtest (VR). The VR Subtest is one of the tasks from Form I of the WMS (Wechsler, 1945). Scoring and administration of the Immediate Phase were identical to that described in the original WMS manual. However, 30 min after completion of the Immediate Phase, subjects were given a sheet of 8 1/2 × 11 inch unlined, white paper and told, "Earlier I had you draw some designs from memory. I'd like to see how many of those designs you can draw now from memory. Please make yours as much like the original designs as possible." Scoring guidelines for the Delayed Phase were identical to those in the original manual.

Vigilance Test. The Vigilance Test is a timed number cancellation task designed to measure attention and concentration. The test consists of a series of random, single-digit numbers arranged in 31 rows, each row containing 35 numbers. The subject is instructed to begin in the upper left-hand corner and work across each row, circling the number "5" each time it appears. There are 111 fives on the page. The test can be scored for number of errors or the length of time to complete the task. The time score was the variable used for this study.

Procedure

Subjects were administered the CVMT, VSRT, EPAT, VR Subtest, and Vigilance Test in the manner described previously. The WAIS-R subtests (i.e., Information, Digit Span, Picture Completion, and Block Design) and the Shipley Vocabulary subtest were administered following standard procedures.

RESULTS

Principle axis factor analysis was used to examine the structure of the CVMT. Two sets of two factor analyses each were performed on the CVMT and marker variable data. Raw test scores were factored in the first set of analyses, and test scores residualized for the effects of age, education, and the age × education interaction were factored in the second set. Within each set of factor analyses, separate analyses were conducted on the immediate and delayed visual memory scores from the CVMT and the WMS VR Subtest.

The number of factors extracted was determined by inspection of the Scree plot of the eigenvalues from an initial principal components analysis. This suggested three factors for the analysis using the immediate visual memory raw scores, and four factors for the analyses employing the delayed visual memory raw scores, and the analyses employing the age and education residualized scores for both the immediate and delayed visual memory tests. These initial solutions were then subjected to principal axis factor analysis, with varimax rotation. Solutions resulting in factors defined by only one variable were rejected. The four orthogonally-rotated principal axis factor solutions are presented in Tables 1, 2, 3, and 4.

Table 1 presents the varimax-rotated, three-factor solution for the analysis using immediate visual memory scores. The initial eigenvalues for this solution were 3.57, 1.35, and 1.06. The final solution accounted for 41.9% of the variance in the correlation matrix, with eigenvalues of 1.88, 1.76, and .97. The first factor, with major loadings from Information and Vocabulary, represents a dimension of verbal intelligence and accounts for 17.1% of the variance. The second factor, with major loadings from Block Design, Picture Completion, and VR Subtest, is a dimension of visual/nonverbal cognitive ability and accounts for 16.0% of the variance. The third factor, with major loadings from the EPAT and VSRT represents a dimension of verbal memory and accounts for 8.8% of the variance. The CVMT loaded equally on factors 1 and 2 (verbal and visual/nonverbal intelligence). It is noteworthy that the immediate scores on both visual memory measures split their loadings between the verbal and nonverbal cognitive factors.

Table 2 presents the varimax-rotated solution for the analysis using delayed visual memory scores. The initial eigenvalues for this solution were 3.34, 1.45, 1.09, and .95. The final solution accounted for 46% of the variance in the correlation matrix, with eigenvalues of 1.86, 1.30, .99, and .91. Similar to

TABLE 1
Factor Analysis Using Immediate Visual Memory Raw Scores

Variable	Factors 1	2	3
CVMT *d'*	.38	.37	.10
WMS VR Immediate	.39	.53	.07
VSRT (CLTR)	–.05	.00	.54
EPAT	.20	.30	.80
WAIS-R Information	.66	.38	.02
Shipley Vocabulary	.92	.08	.00
WAIS-R Picture Completion	.33	.59	–.01
WAIS-R Block Design	.18	.75	.10
WAIS-R Digit Span	.34	.36	.06
Vigilance Test	–.01	–.24	–.09

Note. CVMT = Continuous Visual Memory Test; WMS VR = Wechsler Memory Scale Visual Reproduction Subtest; VSRT (CLTR) = Verbal Selective Reminding Test (Consistent Long-Term Retrieval) EPAT = Expanded Paired Associate Test; WAIS-R = Wechsler Adult Intelligence Scale - Revised.

TABLE 2
Factor Analysis Using Delayed Visual Memory Raw Scores

	Factors			
Variable	1	2	3	4
CVMT Delay	.05	.11	.79	.18
WMS VR Delay	.38	.31	.51	.04
VSRT (CLTR)	–.05	–.04	.10	.66
EPAT	.21	.28	.12	.65
WAIS-R Information	.77	.26	.14	.04
Shipley Vocabulary	.83	.02	.05	.00
WAIS-R Picture Completion	.41	.48	.10	.02
WAIS-R Block Design	.25	.84	.14	.08
WAIS-R Digit Span	.39	.26	.07	.10
Vigilance Test	–.01	–.20	–.15	–.06

the solution in the first analysis, factor 1 is a dimension of verbal intellectual ability, accounting for 16.9% of the variance while factor 2 represents a visual/nonverbal cognitive dimension, accounting for 11.8% of the variance. Factor 3, with loadings from the CVMT Delay and Delayed VR, is a dimension of visual memory, which accounts for 9% of the variance whereas factor 4 represents a dimension of verbal learning and memory, accounting for 8.3% of the variance.

The varimax-rotated solutions obtained for the factor analyses using immediate and delayed visual memory scores residualized for age, education, and the age × education interaction are presented in Tables 3 and 4, respectively. These analyses were based on the difference between the actual raw score for each subject and the score predicted for each subject based on a regression equation utilizing age, education, and the age × education interaction. In this manner, the raw scores are "adjusted" for individual differences in age and education.

Table 3 presents the four-factor solution for immediate visual memory scores. The initial eigenvalues for this rotation were 3.56, 1.31, 1.00, and .92. The final solution accounted for 45.9% of the variance, with eigenvalues of 1.59, 1.48, 1.03, and .95. The first factor represents a visual/nonverbal intellectual dimension, accounting for 14.5% of the variance, whereas the second defines a verbal intellectual dimension, accounting for 13.5% of the variance. The third factor, defined primarily by Digit Span, with secondary loadings from Picture Completion and CVMT d', likely represents an attentional dimension, and accounts for 9.3% of the variance. The fourth factor, with loadings from VSRT and the EPAT, represents verbal learning and memory, accounting for 8.6% of the variance. CVMT d' correlated modestly with both the verbal cognitive and attentional factors, while Immediate VR correlated primarily with the first factor (visual/nonverbal intelligence) and secondarily with the second factor (verbal intelligence).

TABLE 3
Factor Analysis Using Immediate Visual Memory Scores with Age and Education Residualized

	Factors			
Variable	1	2	3	4
CVMT *d'*	.17	.32	.37	.07
WMS VR Immediate	.48	.35	.20	.07
VSRT (CLTR)	–.14	–.05	.10	.72
EPAT	.31	.23	.05	.61
WAIS-R Information	.39	.50	.34	.12
Shipley Vocabulary	.17	.91	.19	.08
WAIS-R Picture Completion	.42	.30	.43	–.03
WAIS-R Block Design	.90	.08	.18	.09
WAIS-R Digit Span	.16	.12	.68	.12
Vigilance Test	–.16	–.11	–.07	.05

Table 4 presents the four-factor, varimax-rotated solution obtained using age and education residualized delayed visual memory scores. The initial eigenvalues for this solution were 3.33, 1.33, 1.08, and 1.00. The final solution accounted for 47.9% of the variance, with eigenvalues of 1.95, 1.23, 1.22, and .89. The first factor is defined primarily by Information and Vocabulary and represents a dimension of verbal intellectual functioning, accounting for 17.7% of the variance. The second factor, defined primarily by Block Design with a secondary loading from Picture Completion, is a visual/nonverbal cognitive factor, accounting for 11.1% of the variance. The third factor represents verbal learning and memory, accounting for 11.0% of the variance while the fourth factor represents a dimension of visual memory, accounting for 8.1% of the variance.

TABLE 4
Factor Analysis Using Delayed Visual Memory Scores with Age and Education Residualized

	Factors			
Variable	1	2	3	4
CVMT Delay	.05	.05	.12	.68
WMS VR Delay	.39	.22	.01	.52
VSRT (CLTR)	.00	–.01	.86	.02
EPAT	.25	.24	.46	.16
WAIS-R Information	.74	.25	.10	.19
Shipley Vocabulary	.77	.04	.04	.17
WAIS-R Picture Completion	.53	.36	–.01	.07
WAIS-R Block Design	.29	.89	.05	.16
WAIS-R Digit Span	.39	.22	.14	.05
Vigilance Test	–.11	–.12	.07	–.11

The reader will note that the initial eigenvalues for factor 4 in the second factor analysis (delayed visual memory raw scores) and in the third factor analysis (immediate visual memory scores residualized for age and education) were below the traditional cutoff of 1.0. However, the meaningfulness of these solutions is supported by both the Scree plot, and by the final rotated principal axis solutions in Tables 2 and 3, which showed convergence of more than one test loading on each of the four factors. In this respect, it is important to note that the Kaiser-Guttman criterion (eigenvalue > 1.0) is a lower-bound (i.e., minimum) solution to the number of factors, and is applicable only to principal components and not to principal axis solutions (Gorsuch, 1983).

DISCUSSION

Data from this study demonstrate that the CVMT delayed score is a factorially "pure" measure of visual memory. The CVMT *d'* score, however, showed generally equivalent, though modest, associations with both verbal and visual intellectual factors in the nonresidualized analysis. In the factor analysis employing scores adjusted for age and education, CVMT *d'* reflected modest associations with verbal intellectual and attentional dimensions. These factorial results for the CVMT are quite similar to previously reported data for the Russell (1975) administration of WMS VR and the Benton Visual Retention Test (BVRT; Larrabee et al., 1985). Larrabee et al. (1985) found that the BVRT, which requires only immediate reproduction from memory, reflected a loading pattern divided among attentional, visual intellectual, and memory factors. A similar pattern was obtained for WMS Immediate VR. In contrast, WMS Delayed VR loaded more closely with WMS Paired Associate Learning and Logical Memory, than with attentional or intellectual factors.

Larrabee et al. (1985) hypothesized that a separate factor for visual memory was not obtained because there was no other delayed visual memory test in their study. Data from the present study support this prior hypothesis. CVMT Delay and WMS Delayed VR scores were found to define a separate dimension of visual memory.

The present study also shows that residualization of scores for the effects of age and education does little to change the factor structure. Similar findings have been reported for factor analyses conducted on age-residualized computer-simulated everyday memory tests (Crook & Larrabee, 1988) and CVLT scores residualized for the effects of age (Delis et al., 1988). Thus, while the CVMT and other memory tests used in this study are sensitive to level of performance differences associated with age, the similarity of factor structure using residualized versus nonresidualized scores suggests that these memory tests are measuring the same material — and modality-specific memory abilities at all adult ages. The test manual for the CVMT (Trahan & Larrabee,

1988) reports analyses of education effects that are nonsignificant. Hence, the lack of education effects on factor structure is not surprising.

The present data were collected from normal subjects, who frequently show less test-score variability than is found in clinical samples. Replication of this study with a clinical sample employing additional measures of verbal and visual memory, verbal and visual intelligence, and attentional skills should yield further support for the factorial validity of the CVMT. The increased score variability in clinical samples may lead to more sharply defined factor patterns. In the current study, for example, there was no clearly identified attentional factor, although marker variables were chosen in an attempt to identify such a dimension. Additionally, the CVMT *d'* score might demonstrate more robust loadings and a more clearly-defined pattern in factor analyses of data based on clinical patients.

Finally, the present data highlight a more general principle underlying the factor structure of verbal and visual memory tests. The acquisition trials of verbal learning and memory tests such as the VSRT, EPAT, WMS Logical Memory, and Paired Associate Learning typically have shown independence from intellectual and attentional factors (Larrabee, Kane, & Schuck, 1983; Larrabee et al., 1985). In contrast, the present data and previous research (Larrabee et al., 1983, 1985) show that acquisition trials of visual memory tests are more closely associated with intellectual and attentional abilities, than with performance on other memory tests. Factorially "pure" measures of visual memory have been obtained only when delayed recall or delayed recognition scores were employed.

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