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Construct Validity of the Continuous Recognition Memory Test*

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ABSTRACT

A principal factor analysis was performed on variables derived from a neuropsychological battery administered to 100 healthy young adults in order to investigate the construct validity of the Continuous Recognition Memory test (CRM). It was hypothesized that CRM ''hits'' and ''false alarms'' would load on different factors. The factors that emerged in the analysis were labeled ''Verbal Ability'', ''Divided Attention'', ''Attention to Visual Detail'', ''Visuomotor Integration and Planning'', and ''Learning and Memory''. As expected, CRM hits had a significant loading on the Learning and Memory factor. However, CRM false alarms did not have a significant loading on the Divided Attention factor as expected and, instead, loaded significantly on the Attention to Visual Detail factor. A second analysis was performed using variables from the delayed condition of the memory measures. In this analysis, the CRM delayed recognition variable had significant loadings on both a ''Nonverbal Memory'' factor and a ''Verbal Memory'' factor. These analyses support the construct validity of CRM hits as a measure of learning and memory and suggest that false alarms provide a measure of attention to visual detail.

The Continuous Recognition Memory test (CRM) was designed to assess memory deficits in patients with closed-head injuries (Hannay & Levin, 1988a). Unlike many memory measures that call for a written or multiword verbal response, the CRM makes minimal response demands on the subject thus making it possible to assess memory in individuals with motor and/or speech output deficits. Performance on the CRM has been shown to be related to severity of injury but not to age, sex, or educational level in adolescents and adults (Hannay & Levin, 1988b, Hannay, Levin, & Grossman, 1979).

The CRM consists of 120 stimulus cards with a black and white line drawing of a familiar, living object on each. After presentation of the first block of 20 stimulus drawings, 8 of the stimulus drawings are repeated in each of the subsequent five blocks interspersed with drawings that are semantically and/or perceptually similar as well as with drawings that are dissimilar. The subject's task is to respond with the word ''old'' every time a drawing is presented that is identical to one previously presented and ''new'' each time a drawing is presented for the first time. In this way, the CRM was designed as an analogue to a signal detection task; a subject can correctly identify a previously seen target item (a hit), incorrectly reject a previously seen item (a miss), incorrectly identify a new item (a false alarm), or correctly reject a new item (a correct rejection). As in the case of a signal detection task, there are two types of trials: a ''signal plus noise'' trial in which the target is pre-

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sented and the subject's response will either be scored as a hit or a miss; and a ''noise only'' trial in which a correct rejection or false alarm is scored. The total correct score for the CRM consists of the number of hits plus the number of correct rejections (which equals hits plus 60 minus the number of false alarms).

Because the stimulus drawings are of familiar living things, Hannay and Levin (1988b) point out that the test may be less confusing to impaired subjects than other memory tests which utilize geometric or nonsense designs. Even though the items are presented visually and not named by the examiner, they lend themselves to verbal description and thus could be encoded verbally and/or nonverbally. In this way the task was designed not to be lateralizing, and studies with head-injured subjects have supported this premise (Hannay et al., 1979, Hannay & Levin, 1988b). Because poor performance on the CRM could be due to impaired visual-perceptual abilities rather than memory deficits, a discrimination post-test is given to subjects to investigate this possibility. The discrimination test consists of eight pages each with one of the target stimulus drawings at the top and six drawings below – one identical to the target and five perceptually similar drawings from the same semantic category. If a subject has difficulty discriminating the target drawing from the distracters, failure on the CRM may be attributable to impaired visual-perceptual processing (Hannay & Levin, 1988a).

The CRM has been shown to be sensitive to the diffuse effects of head injury in that it is not lateralizing and can discriminate between levels of severity of injury (Hannay et al., 1979). However, as Loring and Papanicolaou (1987) point out, our constructs of cognitive operations should not be based solely on tests sensitive to brain damage. In other words, although the CRM renders discriminating data, we are not yet certain if it measures memory, attention, visual perception, a combination of these, or other cognitive operations. For instance, Walker (1991) found that performance on the CRM during recovery from head injury was a good overall predictor of subsequent vocational performance, but was not related to subsequent on-the-job memory ratings. Kaufmann, Fletcher, Levin, Miner, and Ewing-Cobbs (1993) found that CRM hit and false alarm scores did not correlate with each other in a sample of adolescents post head injury and proposed that the two scores measure different and perhaps independent abilities. They also suggested that disinhibition and impulsivity accounted for much of the variance in the CRM total score.

In an exploratory factor analysis using data from neurologically intact young adults, Drake, Hannay, and Burkhart (1993) obtained a four-factor solution in which the CRM hits loaded highly on a ''General Learning and Memory'' factor, but not on a ''Visual/Perceptual/Motor'' factor. The General Learning and Memory factor included measures of both verbal and nonverbal memory and thus did not support a dissociation of these memory abilities. This lack of dissociation is a common finding in factor analytic studies (Larrabee & Curtiss, 1995). In the Drake et al. study, the CRM false alarm score loaded significantly on an ''Attention/Concentration'' factor that was distinct from an ''Impulsivity/Disinhibition'' factor. Thus, in contrast to the report of Kaufmann et al., Drake et al. concluded that CRM scores do not relate to disinhibition in cognitively intact adults. Additionally, because they loaded on different factors, CRM hit and false alarm scores appear to be indices of different abilities, and important clinical information about test performance would be obscured by combining hits and false alarms into a total correct score.

Drake et al. also included a separate analysis involving delayed memory measures. The CRM delayed recognition test is given 30 min after completion of the CRM and prior to the discrimination post-test. It utilizes the eight-page discrimination post-test booklet but with the target drawing at the top of each page covered. The subject is asked to pick out the drawing that was presented many times during the test (the one that was ''old'') from a group of drawings that includes the ''old'' target stimulus and the perceptually similar drawings that were used as distracters during the test. Although the subject has been previously exposed to all the drawings, only the target drawing was presented a total of six times during the initial test. In the analysis using delayed memory variables, Drake et al. obtained a three-factor solution similar to that obtained for the immediate condition. The CRM delayed recognition memory variable loaded with other delayed memory variables on a single factor distinct from a Visual/Perceptual/Motor factor and a Disinhibition/Impulsivity factor. CRM false alarms were not included in the delayed condition analysis as they are part of the immediate, input condition. Thus the second analysis resulted in only a three-factor solution with no factor reflecting an attention/concentration construct.

In a recent factor analytic study investigating the construct validity of verbal and visual memory tests, Larrabee and Curtiss (1995) utilized data from neuropsychological test batteries given to a variety of individuals seen as outpatients in a neuropsychological private practice. The sample was heterogeneous in term of age (16 to 70), education (7 to 18 years), and diagnosis (i.e., individuals with neurological findings were included with those who had received psychiatric diagnoses only). Separate analyses were performed utilizing variables for immediate and delayed conditions of the memory measures. For the immediate condition, the CRM total correct score loaded with the Continuous Visual Memory Test (CVMT) total correct score, the number of words consistently recalled in Verbal Selective Reminding (CLTR score), the Serial Digits (a supraspan digit sequence learning test) score, and a score for a modified version of the Wechsler Memory Scale (WMS) paired associates test on a factor the authors called ‘‘General (Visual and Verbal) Memory’’. Other factors that emerged in the analysis included a ‘‘Visual-Spatial Intelligence/Ability’’ factor with high loadings from WAIS-R Block Design, Object Assembly, Trail Making Part B, and Visual Reproduction from the WMS; an ‘‘Attention/Immediate Memory and Information Processing’’ factor consisting of loadings from the Paced Auditory Serial Addition Test, Digit Span, Serial Digits, and WMS Mental Control; and a ‘‘Verbal Intelligence/Ability’’ factor consisting of loadings from WAIS-R Information and Vocabulary subtests. It should be noted that CRM hits and false alarms were not considered separately in the analysis. Although the results of the study indicated that the CRM is a measure of general memory, more fine-grained information regarding the processes involved in test performance may have been obfuscated by the failure to separate the total score into its hit and false alarm components, as was done in the Drake et al. study.

Larrabee and Curtiss (1995) obtained similar results for a factor analysis using delayed recall and recognition measures. In that analysis, the CRM delayed recognition score, CVMT delayed recognition score, Verbal Selective Reminding delayed recall score, modified paired associate delayed recall score, Serial Digits score, and WMS delayed Visual Reproduction score all loaded on a ‘‘General Memory’’ factor. The other three factors that emerged in the second analysis were defined in the same manner as in the first analysis. Because the WMS Visual Reproduction score loaded on the General Memory factor in the delayed condition only, the authors suggested that the CRM and CVMT may be considered ‘‘purer’’ measures of memory. A possible reason for this might be that WMS Visual Reproduction acquisition is confounded with visuoconstructive ability whereas CRM and CVMT acquisition are not. An important finding in this study was the lack of a specific, visual memory factor. Instead, measures that employed visual presentation of stimuli loaded on the General Memory factor along with measures that utilized orally presented stimuli. Likewise, measures using verbal material loaded together with measures utilizing pictorial material.

Despite the data that have accumulated thus far on the utility and factor structure of the CRM, further exploration of the construct validity of the CRM in both healthy and neurologically impaired populations remains to be done. The present study used exploratory factor analysis to examine performance by healthy young adults on a large battery of tests to determine if factors tapped by specific tests correlated with variables derived from the CRM such that the underlying factor structure of the CRM could be elucidated. Although this type of work was initiated by Drake et al. (1993), the number and range of variables selected for analysis in that study were not really sufficient. Cattell (1988) advocates for the use of a minimum of two ‘‘marker variables’’ for each factor expected to emerge from the factor analysis. These variables should be selected on the basis of their strong and distinct loadings in previous studies. Cattell also suggests that a factor analysis should include ‘‘background markers’’ – variables that will contrast with the variables of interest . Together, the markers and background markers help to define the factors and thus the constructs under investigation.

Drake et al. did not include variables from measures of verbal ability in their analysis and thus the contribution of verbal abilities to CRM performance may not have been captured. Also, it is perhaps not surprising that they found no dissociation between verbal and nonverbal memory abilities because too few verbal and nonverbal memory measures were used to define separate factors according to guidelines suggested by Cattell (1988), Gorsuch (1988), and Streiner (1994). Likewise, measures of divided and focused attention were inadequately represented. It also appears that the criterion for determining a significant factor loading was applied inconsistently, such that at least one factor (Attention/Concentration) may have been mislabeled. The present study also differs from that by Larrabee and Curtiss (1995) in variable selection, the separation of the CRM total score into its hit and false alarm components, and in subject demographics. The subjects in this study were neurologically intact college students so that data analysis would be relatively uncontaminated by variance resulting from differences in age, education, and clinical diagnosis. At least in that regard, the present study was more similar to the Drake et al. study.

We expected that in our analysis of variables from a neuropsychological test battery, the CRM hit score would load with marker variables for memory abilities on a factor that was distinct from factors defined by measures of language ability, visuoconstructional ability, divided attention, and impulsivity. We also expected that the CRM false alarm score would help define a factor for divided attention. Although Drake et al. (1993) found that the CRM false alarm score loaded on a factor which they called ‘‘Attention/Concentration’’, the processes involved in remembering previously presented target items while rejecting perceptually similar stimuli presented in ‘‘noise only’’ trials seems to better represent the definition of a divided attention task (Lezak, 1995; Van Zomeren & Brouwer, 1994). Additionally, we expected that the CRM false alarm score would not load on a factor defined by measures of impulsivity, if indeed it is a measure of primary attentional abilities and not a measure of impulsivity or disinhibition as suggested by Kaufmann et al. (1993). When delayed condition variables were used in a factor analysis, we expected that the CRM recognition memory score would load on a factor with other measures of memory and that the overall factor structure would be similar to that obtained in the first analysis.

METHOD

Subjects were solicited for participation from undergraduate psychology classes at a large university that draws its students from a racially and economically diverse urban community. Individuals were deemed ineligible for the study if they had a history of closed-head injury, neurological disorder, psychiatric disorder, substance abuse, or learning disability. Of the 122 individuals who consented to participate in the study, 100 subjects produced complete, valid data for analysis (60 females, 35 males, 5 whose sex was not recorded). The median age of the subjects was 19 years (range = 17 to 41 years) whereas the mean age was 21.3 years (*SD* = 5.1 years).

The subjects completed a comprehensive neuropsychological battery over two testing sessions. The tests selected from this battery for analysis were expected to assess the areas of verbal ability (WAIS-R Vocabulary, WAIS-R Information, Controlled Oral Word Association), visuoperception and visuoconstruction (WAIS-R Block Design, WAIS-R Picture Completion, Rey-Osterreith Complex Figure copy, Judgment of Line Orientation), divided attention (Paced Auditory Serial Addition Test total score, Digit Span backward, Trail Making Test, Part B, CVMT false alarms), focused attention (WAIS-R Arithmetic, Digit Span forward, Trail Making Test, Part A), immediate verbal and nonverbal memory (CVMT hits, WMS-R Logical Memory immediate recall, Consistent Long-Term Retrieval from the Verbal Selective Reminding Test), delayed verbal and nonverbal memory (CVMT delayed recognition, Logical Memory delayed recall, Verbal Selective Reminding Test delayed recall, Rey-Osterreith Complex Figure delayed reproduction) and impulsivity (MMPI-2 scale 4, Porteus Mazes qualitative error score, Kagan's Matching Familiar Figures error score). Descriptions of these tests and scoring criteria can be found in Lezak (1995). All delay periods were 30 min, and strict scoring rules were used for the Rey-Osterreith Complex Figure and the Porteus Mazes. Additionally, the variables of interest from the CRM – hits, false alarms, and delayed recognition – were included. Test protocols were scored according to standard scoring procedures given in test manuals.

Raw scores for the variables of interest for all subjects with complete data were entered into two SAS data sets – one in which variables for memory tests were from the immediate condition, and one in which variables for memory tests were from the delayed condition. Raw scores were used rather than scaled or standardized scores to better capture the variability in test performance across subjects in this fairly homogeneous sample. Also, because the tests used in the battery have been normed on different populations, converting the raw scores we obtained to *z* scores or *T* scores might introduce error into the analyses as a result of differences in the normative populations rather than actual variability within our sample.

RESULTS

Initial univariate analysis of the variables indicated that the score distributions for Judgment of Line Orientation and Kagan's Matching Familiar Figures were skewed to the extent that they did not approximate a normal distribution even with mathematical transformation. Examination of the squared multiple correlation of each variable, where it serves as a dependent variable with all other variables in the analysis as independent variables, indicated that the variable derived from the MMPI-2 was not sufficiently related to the other variables in the set. These three variables were thus not included in further analyses.

The variables that remained were subjected to principal factor analysis using the SAS system according to the steps outlined by Tabachnick and Fidell (1989) and by Hatcher (1994). The number of factors to be retained for rotation after initial extraction was determined by a combination of examination of the Scree plot, the amount of variance accounted for by each factor, and the number of variables with significant loadings on each factor.

For the analysis using variables from the immediate condition of the memory measures, a five-factor solution satisfied the criteria recommended by Hatcher as the final factor retained accounted for 10% of the variance in the set of variables, appeared before a drop in the Scree plot, and had significant loadings (>.35) from at least three variables. The five factors were submitted to oblique rotation using Promax, which first produces an orthogonal rotation through Varimax. As the obliquely and orthogonally rotated solutions did not differ substantially, the orthogonal rotation was retained for ease of interpretation.

The process was repeated substituting the delay condition variables for the immediate condition variables of the memory measures. A four-factor solution emerged that satisfied the above criteria and, again, as the orthogonal and oblique rotations did not produce substantially different factor patterns and loadings, the orthogonal rotation solution was retained for interpretation.

Immediate Condition

Means and standard deviations for the variables used in the analysis are given in Table 1. Principal factor analysis produced a five-factor solution using the squared multiple correlation for each variable as its prior communality estimate. Significant factor loadings after orthogonal rotation (≥ .35) are given in Table 2 along with the final communality estimate (h^2) for each variable, the proportion of variance accounted for by each factor, and the proportion of covariance accounted for by each factor.

The first factor to emerge in the analysis accounted for 10% of the total variance in the variable set and 24% of the common variance. It

Table 1. Simple Statistics for the Variables Used in the Analyses (Raw Scores).

	Mean	Standard Deviation
CRM Hits	38.6	1.55
CRM False Alarms	7.9	5.92
CRM Delay	7.3	0.93
WAIS-R Vocabulary	49.3	10.17
WAIS-R Information	19.3	4.12
WAIS-R Arithmetic	13.3	2.52
WAIS-R Block Design	36.4	8.69
WAIS-R Picture Completion	16.3	1.68
WAIS-R Digits Backward	8.1	2.21
WAIS-R Digits Forward	9.2	1.93
PASAT	152.2	24.43
Trail Making Test, Part A	25.4	7.96
Trail Making Test, Part B	49.7	16.01
Controlled Oral Word Association	40.6	9.22
Verbal Selective Reminding Test – CLTR	105.8	26.12
Verbal Selective Reminding Test – Delay	11.3	1.13
Logical Memory – Immediate Recall	31.2	5.93
Logical Memory – Delayed Recall	28.5	6.19
CVMT Hits	37.0	3.34
CVMT False Alarms	8.2	6.31
CVMT Delay	5.6	1.4
Rey-Osterreith Complex Figure Copy	30.8	2.90
Rey-Osterreith Complex Figure Delay	22.9	4.81
Porteus Mazes – Error score	16.0	12.58

contained significant variable loadings from WAIS-R Vocabulary, WAIS-R Information, WMS-R Logical Memory (immediate recall), and WAIS-R Arithmetic and was labeled ‘‘Verbal Ability’’. The magnitude of the factor loadings for Vocabulary and Information were much larger than those for Logical Memory and Arithmetic. Inspection of the final communality estimates also indicated that much of the variance in Logical Memory and Arithmetic was not accounted for in this analysis. However, these variables shared a significant amount of variance with Vocabulary and Information. It is likely that the underlying ability responsible for this covariance was verbal ability in that responses appear to require access to a semantic store and manipulation of verbal information.

The second factor to emerge also contained a significant loading from WAIS-R Arithmetic, as well as significant loadings from PASAT, Digit Span backwards, Controlled Oral Word Association (COWA), and CVMT hits. The Trail Making Test, Part B also showed a significant negative loading on this factor. The negative loading was expected as a high score on this variable is indicative of poor performance (time to complete the task) whereas a high score on the other measures is related to good performance on those tasks. Three of these variables – PASAT, Digit Span backwards, and Trail Making, Part B – were selected for this analysis as marker variables for divided attention, and thus this factor was labeled ‘‘Divided Attention.’’ Although COWA is often thought of as a test of verbal ability, it did not have a significant loading on the Verbal Ability factor. The final communality estimate for the COWA variable indicated that most of the variance was not accounted for in this analysis, and it is possible that only the attentional component of the task was captured on this factor. The Divided Attention factor accounted for nearly 10% of the total variance and 23% of the common variance in the variable set.

Table 2. Orthogonally Rotated Factor Pattern – Immediate Condition.

	1	2	3	4	5	h^2
Vocabulary	**.80**	.05	–.17	–.05	.12	.68
Information	**.72**	.14	–.14	–.03	.26	.62
Logical Memory	**.39**	.23	–.17	.15	.02	.25
Arithmetic	**.39**	**.40**	–.20	.10	–.00	.36
Digits Forward	.33	.21	–.08	–.32	–.04	.27
PASAT	.22	**.74**	–.03	–.05	.11	.62
Digits Backward	.20	**.54**	–.18	–.18	.13	.42
COWA	.03	**.45**	–.09	–.03	–.09	.22
CVMT false alarms	–.08	–.11	**.74**	.15	–.13	.61
CRM false alarms	–.11	–.05	**.72**	.09	.10	.55
Picture Completion	.15	.08	**–.37**	.19	.07	.21
Block Design	.25	.20	**–.43**	.07	.29	.38
Rey Complex Figure Copy	.18	.07	**–.43**	.33	.08	.33
Trail Making Test, Part A	.11	–.20	.08	**.63**	–.08	.47
Trail Making Test, Part B	–.07	**–.44**	–.05	**.50**	–.22	.49
Porteus Mazes	.08	–.29	.13	**–.45**	–.15	.34
CRM hits	.08	–.01	–.04	–.10	**.61**	.39
SRT CLTR	.28	–.07	–.16	.09	**.50**	.37
CVMT hits	–.03	**.38**	.03	.04	**.47**	.37
Proportion of Variance	10%	9.8%	9.5%	6.5%	6.2%	Total Variance = 42%
Proportion of Covariance	24%	23%	22%	16%	15%	Total Covariance = 100%

Note. Loadings ≥ .35 were deemed significant.

Marker variables for focused attention also were included in the analysis – WAIS-R Arithmetic, Digit Span forward, and the Trail Making Test, Part A. These variables did not load together to form a distinct factor as Arithmetic loaded significantly on the Verbal Ability and Divided Attention factors, Digit Span forward had loadings that approached but did not reach significance on the first and fourth factor, and Trail Making, Part A loaded significantly on the fourth factor only.

The third factor to emerge in the analysis accounted for 9.5% of the total variance and 22% of the common variance. This factor was defined by significant loadings from the false alarm variables from the CRM and CVMT, WAIS-R Picture Completion, WAIS-R Block Design, and the Rey-Osterreith Complex Figure copy. It was expected that the sign of the loadings from the false alarm variables would be opposite of that from the other variables, as a high false alarm score is indicative of poor performance. The variables for Picture Completion, Block Design, and the Rey-Osterreith Complex Figure were selected for analysis as marker variables to define a ‘‘Visuoperception and Visuoconstruction’’ factor, but this factor might be better labeled ‘‘Attention to Visual Detail’’. The high loadings from the CRM and CVMT false alarm variables on this factor indicate that the false alarm scores were more related to attention to visual detail than other abilities, such as divided attention.

The fourth factor was labeled ‘‘Visuomotor Integration and Planning’’ as it was defined by variables that involved manipulating a pencil under a time pressure to plan and execute a route from one point to another. This factor accounted for 6.5% of the total variance and 16% of the common variance and was defined by significant loadings from Trail Making, Part A, Trail Making, Part B, and the qualitative error score from Porteus Mazes. Whereas the variables for Trail Making Parts A and B are reflective of speed of performance and had positive loadings on this factor, the variable from Porteus Mazes is related to accuracy of execution regardless of speed and had a negative loading. Thus, a high score on the Trail Making Test and a low error score for Porteus Mazes might indicate a planned, careful response to a visuomotor task.

The final factor to emerge in the analysis accounted for 6.2% of the total variance and 16% of the common variance. This factor was labeled ‘‘Learning and Memory’’ as it contained significant loadings from CRM hits, CVMT hits, and Consistent Long-Term Retrieval (CLTR) from the Verbal Selective Reminding Test. This variable was not simply labeled ‘‘memory’’ as the three measures rely on learning repeated stimuli unlike other variables with immediate recall conditions such as WMS-R Logical Memory and Digit Span forward.

Delay Condition

Principal factor analysis was repeated using delay rather than immediate condition variables for the memory measures. There were fewer variables in this analysis because hits and false alarms from the CRM and CVMT were replaced by the delayed recognition memory measures from each of these tests. Significant factor loadings after orthogonal rotation are given in Table 3 along with the final communality estimate (h^2) for each variable, the proportion of variance accounted for by each factor, and the proportion of covariance accounted for by each factor.

The first factor to emerge in the analysis accounted for 10% of the total variance in the variable set and 23% of the common variance. Similar to the immediate condition analysis, it contained significant variable loadings from WAIS-R Vocabulary, WAIS-R Information, and WAIS-R Arithmetic. In this analysis, the loading from Digit Span forward reached the significance criterion (≥ .35). As in the immediate condition analysis, this factor was labeled ‘‘Verbal Ability’’.

The second factor to emerge accounted for 10% of the total variance in the set and 22% of the common variance. This factor was nearly identical in variable composition and magnitude of loadings to the second factor in the immediate condition and was likewise labeled ‘‘Divided Attention’’.

The third factor accounted for 9.7% of the total variance and 21% of the common variance in the variable set. Like the third factor from the

Table 3. Orthogonally Rotated Factor Pattern – Delayed Condition.

	1	2	3	4	5	h2
Vocabulary	**.78**	.10	.02	.24	–.01	.67
Information	**.72**	.15	.20	.23	–.00	.64
Digits Forward	**.38**	.20	.03	–.01	–.25	.25
Arithmetic	**.37**	**.42**	.19	.11	.13	.38
PASAT	.18	**.75**	.11	.02	–.12	.63
Digits Backward	.21	**.54**	.14	.07	–.19	.40
COWA	.03	**.43**	.10	–.07	–.07	.20
Picture Completion	.19	.08	.33	–.10	.07	.17
Block Design	.30	.16	**.67**	.01	.00	.57
Rey Complex Figure Delay	–.18	.14	**.61**	.32	.19	.56
CVMT Delay Recognition	–.00	.17	**.59**	.26	–.17	.47
CRM Delay Recognition	.08	–.05	**.43**	**.57**	–.04	.52
SRT Delay Recall	.14	–.08	.04	**.60**	–.10	.40
Logical Memory Delay	.26	.19	.04	**.54**	.18	.43
Trail Making Test, Part A	.03	–.15	–.05	.02	**.70**	.52
Trail Making Test, Part B	–.07	**–.40**	.08	–.17	**.60**	.56
Porteus Mazes	.16	–.31	–.23	–.15	**–.37**	.34
Proportion of Variance	10%	10%	9.7%	7.9%	7.3%	Total Variance = 45%
Proportion of Covariance	23%	22%	21%	17%	16%	Total Covariance = 100%

Note. Loadings ≥ .35 were deemed significant.

immediate condition analysis, this factor contained significant loadings from the WAIS-R Block Design variable, as well as the delayed memory variables from the Rey Complex Figure, the CRM, and the CVMT. Notably, WAIS-R Picture Completion failed to produce a significant loading in this analysis and its final communality estimate (.17) indicates that it did not share a great deal of variance with the other variables in this analysis. Although the Rey Complex Figure, CRM, and CVMT variables were all from delayed memory conditions, WAIS-R Block Design was not. It is not entirely clear why Block Design loaded on this factor (perhaps because all the measures involve visual perception), but the factor was deemed a ''Nonverbal Memory'' factor.

The fourth factor accounted for 7.9% of the total variance and 17% of the common variance in the delay condition analysis. This factor was defined by significant loadings from CRM delayed recognition, Verbal Selective Reminding delayed recall, and WMS-R Logical Memory delayed recall. The latter two variables are clearly based on verbal material and, as it appears that the nonverbal aspects of the CRM recognition variable were captured on the third factor, it is likely that the significant loading from the CRM recognition variable on this factor represented the verbal encoding aspect of the CRM stimuli. Thus, this factor was labeled ''Verbal Memory''.

The final factor to emerge accounted for 7.3% of the total variance and 16% of the common variance in the variable set. This factor was identical in variable loadings with similar loading magnitudes to the fourth factor in the immediate condition analysis and was thus labeled ''Visuomotor Integration and Planning''.

DISCUSSION

The present analyses support the construct validity of the CRM as a measure of learning and memory. Importantly, the two components of the CRM total score – hits and false alarms – loaded on separate factors indicating that these variables are indices of different abilities within the same test. CRM hits loaded with other variables that defined a Learning and Memory factor whereas CRM false alarms loaded significantly on a factor defined by measures requiring attention to visual detail. The other factors that emerged in the analysis of the immediate condition variables were labeled Verbal Ability, Divided Attention, and Visuomotor Integration and Planning. Further, the analysis using delayed memory measures again supports the proposition that the CRM stimuli can be encoded verbally or nonverbally, as the CRM delay variable showed significant loadings on both the verbal and nonverbal memory factors.

We expected that CRM hits and false alarms would load on separate factors in this analysis. It may not be intuitively obvious that hits and false alarms would depend on different cognitive abilities; however, as the CRM was constructed as an analogue to a signal detection task, hits and false alarms occur under two different test conditions. False alarms occur in ''noise only'' trials where the stimuli have not been previously presented. Good performance is thus dependent upon attention to visual detail. If attention is not paid to the details of the stimuli, differences between targets and distracters may not be readily apparent and a subject may endorse a distracter item as one that had been previously seen because it is perceptually or semantically ''close'' to a previously seen target. Prior to our analysis, the process that occurs in noise only trials appeared to us to meet the definitions for divided attention provided by Lezak (1995) and Van Zomeren and Brouwer (1994). One class of information (previously seen items) must be remembered while an operation (attention to visual detail) is performed on a task-related item and a match/no match decision is made. However, our analysis suggests that it is not divided attention but attention to visual detail that is measured by the CRM false alarm score. Hits occur in ''signal plus noise'' trials in which all stimuli have been previously seen and thus the task is one of recognition memory – all items thus should ''match'' the memory trace of the item even if the subject is unsure of the details of the drawing. Additionally, the target items are presented several times in the course of the test.

This should strengthen the memory trace (i.e., learning) of the target and make it easier to recognize as the test progresses. CRM hits did indeed load on the Learning and Memory factor. Though the false alarm variable from the CVMT differs from that of the CRM in that the CVMT utilizes abstract line drawings rather than drawings of recognizable living things, they both showed significant loadings on the same factor indicating that the cognitive process that supports test performance is similar regardless of the type of stimuli used.

Following the recommendation of Cattell (1988), some of the variables used in the analyses were selected as ‘‘marker variables’’ for certain abilities to help define and label the factors that emerged. As expected, WAIS-R Information and Vocabulary loaded together to help define the Verbal Ability factor, PASAT and Digit Span backward defined the Divided Attention factor, Block Design, Picture Completion, and copy of the Rey-Osterreith Complex Figure defined what we initially were inclined to call a Visuoperception/Visuoconstruction factor but is most likely an Attention to Visual Detail factor, and the CVMT hits and Consistent Long-Term Retrieval from the Verbal Selective Reminding Test helped define the Learning and Memory factor. However, some of the variables selected for the analyses did not ‘‘behave’’ as expected. Notably, variables for the MMPI-2 (Scale 4) and Kagan’s Matching Familiar Figures Test were dropped from the analyses due to poor correlation with other variables and extremely skewed score distributions. These variables were expected to load together to define a factor for disinhibition/impulsivity, and without these variables in the analysis, no such factor emerged. It may be that a clinical population would produce greater variability in scores on these measures such that these variables could be included in an analysis.

Also, it was expected that the variables from WAIS-R Arithmetic, Digit Span forward, and Trail Making, Part A would define a factor for focused attention. This factor did not emerge as Digit Span forward failed to load significantly on any factor in the immediate condition analysis, and Arithmetic loaded on both the Verbal Ability and Divided Attention factors. The variance from Trail Making, Part A was captured on a factor that seemed best labeled Visuomotor Integration and Planning as that factor also included significant loadings from Trail Making, Part B and the qualitative error score from Porteus Mazes.

Another unexpected finding was that the variable from the Controlled Oral Word Association did not load on the Verbal Ability factor whereas the immediate recall variable from the WMS-R Logical Memory did. This finding is striking, as COWA is often considered a test of verbal fluency, and it has been shown to correlate highly with vocabulary (desRosiers & Kavanagh, 1987). However, Ruff, Light, Parker, and Levin (1997) have shown that COWA correlates as well with Digit Span (.45) as with Vocabulary (.41) in a large sample of healthy adults. They propose that the abilities tapped by COWA are word knowledge, as well as attention and concentration in order to avoid breaking the rules under a speeded condition.

Factor analytic studies of neuropsychological test variables with mixed populations (neurologic and psychiatric patients) have shown that Logical Memory I consistently loads highly on a visual/verbal memory factor and also produces a smaller but significant loading on a verbal ability/verbal expression factor (Larrabee, Kane, Schuck, & Francis, 1985; Ryan, Rosenberg, & Mittenberg, 1984). The low final communality estimates (h^2) for COWA (.22) and Logical Memory (.25) in the immediate condition analysis indicates that much of the variance in these measures was not accounted for in the analysis. Thus, it may be the secondary features – divided attention for COWA and verbal ability for Logical Memory – that were captured in the present study. In the delay condition analysis, the final communality estimate for Logical Memory was much higher (.43), and this variable loaded, as expected, with measures of verbal memory.

In contrast to other factor analytic studies (Drake, Hannay, & Burkhart, 1993; Larrabee & Curtiss, 1995; Larrabee et al., 1985), the analysis using delay condition variables from the memory measures supported a dissociation between memory for verbal material and nonverbal material. Although CRM and CVMT hits loaded together in the immediate condition analysis, and delayed recognition from these tests loaded together on the Nonverbal Memory factor, only the CRM delayed recognition also showed a significant loading on the Verbal Memory factor along with the Verbal Selective Reminding delayed recall and the Logical Memory delayed recall. It appears that in the immediate condition, the learning aspect of the CRM, CVMT, and Verbal Selective Reminding predominates as these three tests utilize repeated stimuli whereas Logical Memory does not utilize repeated stimuli and, in fact, did not load with these other variables in the immediate condition. However, recall and recognition after a delay may rely more on the manner in which the material was encoded and thus the verbal and nonverbal aspects of memory are more separable. If this be the case, the results from this study support the contention of Hannay and Levin (1988b) that the CRM is a nonlateralizing test of memory function as performance on the CRM delayed recognition appears to draw from both verbal and nonverbal memory abilities.

In contrast to the Drake et al. (1993) factor analytic study of the CRM, this study included a wider range and number of variables to help define the factors, as well as clearer decision rules as to the designation of significant factor loadings. This study also differed from that of Larrabee and Curtiss (1995) in variable selection and in the use of a neurologically intact population. Although the current study represents a further definition of the constructs that underlie performance on the CRM, there are some limitations that should be pointed out. Whereas the subject to variable ratio remained above that commonly recommended (Streiner, 1994; Tabachnick & Fidell, 1989), the sample size just meets the minimum requirements given for performing a factor analysis. With a minimum sample size, it may be that the factor structure that emerged is unstable and would not be obtained in a similar sample of 100 or more subjects. Additionally, the individuals who participated in the study were young adults with some college education. Thus, the results from this study might not generalize to other populations, such as older individuals or individuals with neurological disorders. However, the results of the current study provide a useful contrast to other studies which utilize the CRM.

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