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Forward and Backward Memory Span Should Not Be Combined for Clinical Analysis

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The practice of combining forward and backward memory span, as represented so prominently on the various Wechsler Scales, to arrive at a composite score for clinical interpretation is examined historically and actuarially using a large (N = 1,342) nationally stratified random sample of children from ages 5 years through 19 years. Past literature does not support the additive nature of forward and backward memory span as elements of a common process. Factor analyses of forward and backward recall using both digits and letters indicate that the two memory processes are distinct as well and should not be combined for clinical interpretation. © 1997 National Academy of Neuropsychology

Memory is a key feature of cognitive processes in humans and is represented in nearly all day to day functions, be they intellectual, academic, social, vocational, or recreational. Memory allows us to acquire skills and knowledge, to perform our jobs, and to recognize and respond appropriately to our loved ones. Simply put, memory is ubiquitous in daily life and allows us to develop and maintain an identity. Any comprehensive model of cognitive processes or neuropsychological functions, such as those suggested by Bennett (1992), Halstead (1947), Reitan and Wolfson (1985), and Reynolds and Bigler (1994a), must designate key roles for memory. Memory also was one of the first studied of mental processes at the birth of psychology as a science. Wundt (1906), in his efforts to understand and measure the scope of consciousness, conducted a number of experiments with regard to memory and memory traces. Ebbinghaus (1885) built an entire field of study around memory in the earliest days of our discipline. Neuropsychologists have found memory to be crucial to understanding basic functional neuroscience and to clinical practice (e.g., see Heilman & Valenstein, 1979; Golden & Vicente, 1983, Kolb & Whishaw, 1990; Kupfermann, 1991; LaRue, 1992). Impaired memory is the most frequent cognitive complaint of brain-injured patients (Golden & Vicente, 1983) and is a central feature of the vast majority of the dementias. Memory problems often accompany learning disabilities, extremely low birth weight, neurotoxic

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disorders, seizure disorder, and a variety of CNS diseases during childhood and adolescence (Reynolds & Bigler, 1994a).

From the beginnings of individual intellectual assessment for clinical purposes (e.g., Binet & Simon, 1905) through the current history of the singularly successful Wechsler Scales (e.g., see Reynolds & Kaufman, 1985, for a review), memory has been included as a specific component of formal testing. Forward and backward recall of digits, considered separately by Binet, was included from the beginning of efforts at clinical assessment of intelligence and combined into a single subtest by Wechsler (1939). Thus on the most often used measures of intelligence and memory (the various Wechsler intelligence scales and the various versions of the Wechsler Memory Scale) forward and backward memory span are summed as raw scores prior to developing a standardized or scaled score that is interpreted often to represent short-term memory.

Memory is a relatively complex phenomenon and subtle changes in task demands, can lead to significant changes in performance. This is in part what has lead to the plethora of designation of "types" of memory. Reynolds and Bigler (1994a) note more than 40 terms proffered by various researchers to represent forms of memory. With so many forms of memory distinguishable, at least conceptually, it is not clear that forward and backward memory span are a common skill with a single or nearly single latent skill accounting for performance on both tasks.

Ramsay and Reynolds (in press) reviewed 76 studies of performance on digit span tasks and concluded that forward and backward digit span had some similarities, but the differences in the two tasks were greater than their similarities; and, the differences appear to have important diagnostic and neurologic implications. This possibility has been suggested for some time and has prompted the publisher of the Wechsler scales to provide some limited information, for the first time, on how the two tasks might differ (Wechsler, 1991). Wechsler (1991) provides tables (B.6 and B.7) that provide information on cumulative percentages of longest digit span, separately for forward and backward span, and the cumulative percentage of the difference between longest digits forward and digits backward span. As many as 3% of children, at some ages, actually have a longer backward than forward span. The fact that children show a forward span greater than backward span at a 33:1 ratio (in raw score form) suggests in itself that the two tasks are far from equivalent; but these tables provide little information of any clinical utility. A table of scaled score comparisons would be more useful.

Jensen (e.g., Jensen, 1980; Jensen & Figueroa, 1975) has suggested that the two tasks (Forward Digit Span, FD, and Backward Digit Span, BD) differ in the requirement of an element of transformation on BD that is not present on FD. Jensen and Figueroa (1975) found the two tasks to behave rather differently across ethnic groups as well. The Black-White difference in their study was twice as large on BD as FD. BD was also found to be correlated with IQ at a much higher level than FD. A number of studies suggest that FD may have a verbal element (e.g., de Renzi & Nichelli, 1975) and BD a visuopatial element (e.g., Rapport, Webster, & Dutra, 1994). The two tasks may also be differentially impaired by damage to different cortical and subcortical structures (Black, 1986; Black & Strub, 1978; Benson, Cohen, & Zarcone, 1978).

In designing the Kaufman Assessment Battery for Children (K-ABC; Kaufman & Kaufman, 1983), the Kaufmans took note of the probable processing differences in FD and BD as well and included only a FD task on the K-ABC. They also relied upon two neuropsychological studies (Costa, 1975; Weinberg, Diller, Gerstman, & Schulman, 1972) noting that the two tasks functioned differently in neurologic patients.

Some purely psychometric research also points to distinct latent abilities for FD and BD. Woodward, Svinicki, and Carrow-Woolfolk (1987) factor analyzed the performance of 1,032 children aged 4 to 10 years on DB and on the Carrow Auditory-Visual Abilities Test. These researchers found evidence for two factors. FD loaded on a first factor that included sequential and verbal, but not on a second factor that encompassed visual, motor, and visuomotor subtests, along with an auditory blending subtest. By contrast, BD did not load clearly on either factor. A purely visuospatial factor might have correlated more highly with BD. Nonetheless, these children's performance resisted easy categorization into a verbal-visual dichotomy.

The Test of Memory and Learning (TOMAL; Reynolds & Bigler, 1994b) contains multiple measures of memory along with a variety of stimuli for forward and backward memory span including digits, letters, and manual gestures. A factor analysis of the TOMAL (Reynolds & Bigler, 1996) revealed a distinct factor for backward recall tasks. Reynolds and Bigler (1996) subsequently argued for the separate scaling of forward and backward memory span tasks. Ramsay and Reynolds (in press) have re-examined these data.

RAMSAY AND REYNOLDS RE-EXAMINATION OF THE TOMAL FACTOR ANALYSIS OF REYNOLDS AND BIGLER (1996)

Ramsay and Reynolds (in press) specifically examined the structure of the TOMAL to determine the appropriateness of separate forward and backward memory span tasks. Reynolds and Bigler (1996) derived a four-factor Promax solution of the 14 TOMAL subtests (described in Table 1) to provide the best dimensionally reduced explanation of the 14 subtests.

In the four-factor Promax solution emphasized by Reynolds and Bigler (1996), and presented in Table 2 for ease of view, the complex first factor included Memory for Stories, Word Selective Reminding, Object Recall, Paired Recall, Facial Memory, and Visual Selective Reminding. According to Ramsay and Reynolds (in press), this factor may reflect an ability to recall or to recognize material previously dismissed from conscious memory. More specifically, examinees:

1. Attend to inputs and commit them to memory,
2. Release the inputs temporarily from conscious memory to attend to additional inputs, and
3. "Think back" to the original items, that is, recall or recognize them. Essentially, each of these subtests exceed examinees' immediate memory span, which, evidence suggests, may have a sequential character. Jensen (1967) found that span and sequential measures load almost identically.

By contrast, the second factor appeared to measure participants' sequential span. Subtests loading on this factor called upon examinees to transform the verbal contents of their sequential span into a visual representation. This factor presents some uncertainty as to its specific content, however, in that only one type of task, the backward span activities, loaded upon it. Finally, the fourth factor may reflect visuospatial memory.

In the two-factor Promax solution (Table 2), the first factor seems to reflect memory for sequence, like factor two of the four-factor solution. The second factor, like factor one of the four-factor solution, may represent memory for material that exceeds an examinee's sequential span. However, the need to reach back to previously relinquished, unconscious material may not make up an essential part of this factor, which correlates also with Abstract Visual Memory and Visual Sequential Memory. In these activities, the maintenance of a two-dimensional, visual plane may predominate. Still, some material may slip into the preconscious realm, where it remains relatively accessible.

Of greatest interest here, however, results for Digits Forward and Backward indicate that:

TABLE 1
Description of TOMAL Subtests

CORE

Memory-for-Stories. A verbal subtest requiring recall of a short story read to the examinee. Provides a measure of meaningful and semantic recall and is also related to sequential recall in some instances.

Facial Memory. A nonverbal subtest requiring recognition and identification from a set of distractors. black and white photos of various ages. males and females. and various ethnic backgrounds. Assesses nonverbal meaningful memory in a practical fashion and has been extensively researched. Sequencing of responses is unimportant.

Word Selective Reminding. A verbal free-call task in which the examinee learns a word list and repeats it only to be reminded of words left out in each case: tests learning and immediate recall functions in verbal memory. Trials continue until mastery is achieved or until eight trials have been attempted: sequence of recall unimportant.

Visual Selective Reminding. A nonverbal analogue to WSR where examinees point to specified dots on a card, following a demonstration of the examiner, and are reminded only of items recalled incorrectly. As with WSR, trials continue until mastery is achieved or until eight trials have been attempted.

Object Recall. The examiner presents a series of pictures, names them, has the examinee recall them, and repeats this process across four trials. Verbal and nonverbal stimuli are thus paired and recall is entirely verbal, creating a situation found to interfere with recall for many children with learning disabilities but to be neutral or facilitative for children without disabilities.

Abstract Visual Memory. A nonverbal task. AVM assesses immediate recall for meaningless figures when order is unimportant. The examinee is presented with a standard stimulus and required to recognize the standard from any of six distractors.

Digits Forward. A standard verbal number recall task. DSF measures low-level rote recall of a sequence of numbers.

Visual Sequential Memory. A nonverbal task requiring recall of the sequence of a series of meaningless geometric designs. The ordered designs are shown followed by a presentation of a standard order of the stimuli and the examinee indicates the order in which they originally appeared.

Paired Recall. A verbal paired-associative learning task is provided by the examiner. Easy and hard pairs and measures of immediate associative recall and learning are provided.

Memory-for-Location. A nonverbal task that assesses spatial memory. The examinee is presented with a set of large dots distributed on a page and asked to recall the locations of the dots in any order.

SUPPLEMENTARY

Manual Imitation. A psychomotor. visually-based assessment of sequential memory where the examinee is required to reproduce a set of ordered hand movements in the same sequence as presented by the examiner.

Letters Forward. A language-related analog to common digit span tasks using letters as the stimuli in place of numbers.

Digits Forward. This is the same basic task as Digits Forward except the examinee recalls the numbers in reverse order.

Letters Backward. A language-related analog to the Digits Backward task using letters as the stimuli instead of numbers.

1. These subtests do correlate, as do Letters Forward and Letters Backward;
2. The Letter Span tests behave much like the Digit Span tests; and finally,
3. The backward span measures display clear differences from their forward counterparts. In the two-factor Promax solution (Table 2), all four span measures clearly loaded on the sequential first factor. In the four-factor promax solution, however (Table 2), only the forward span measures loaded on the sequential second factor. Both backward subtests loaded by themselves on the third factor. None of these subtests loaded heavily on any other factor.

The three-factor Promax solution (Table 3) showed the forward measures loading substantially on the first, sequential factor, with little generalization to other factors. The backward measures behaved differently, having a significantly lower mean loading than the forward measures on the first factor (mean for backward measures is .53; mean for forward measures is .80; difference of .27, $p < .001$) and also correlating somewhat with the largely visuospatial third factor. The forward measures have a mean loading of .08 on the third factor

TABLE 2
Two and Four Factor Promax Solutions of TOMAL Subtests[a]

		Solution Two-Factor[b]		Four-Factor[b]			
Subtest	Factor	1st	2nd	1st	2nd	3rd	4th
Memory for Stories		.17	*.45*	*.37*	.05	.19	.19
Word Selective Reminding		.01	*.67*	*.73*	.08	.03	.13
Object Recall		.05	*.58*	*.57*	.08	.01	.01
Digits Forward		*.71*	.00	.03	*.74*	.05	.06
Paired Recall		*.03*	*.67*	*.68*	.05	.07	.04
Letters Forward[c]		*.78*	.03	.01	*.76*	.10	.03
Digits Backward[c]		*.64*	.06	.06	.10	*.63*	.01
Letters Backward[c]		*.72*	.00	.02	.13	*.66*	.07
Facial Memory		.02	*.47*	*.37*	.01	.08	.24
Visual Selective Reminding		.06	*.45*	.33	.01	.08	.24
Abstract Visual Memory		.14	*.49*	.32	.01	.03	*.39*
Visual Sequential Memory		.28	.34	.26	*.38*	.13	.18
Memory for Location		.24	.12	.06	.00	.09	*.44*
Manual Imitation[c]		*.59*	.09	.02	*.38*	.15	.29

[a]From Reynolds and Bigler (1996).
[b]Loading above .35 are italicized.
[c]Supplementary subtest.

while the mean loading for the backward measures is .31 (difference of .23, $p < .001$). However, visuospatial activity cannot account entirely for examinees' performance on these tasks, because their loading on their own third factor in the four-factor solution almost entirely eclipsed their loading on the apparently visuospatial fourth factor. None of the four subtests loaded appreciably on the factor two of three-factor solution, which loaded almost exactly like the factor two of the two-factor solution, and may reflect memory for material that exceeds an examinee's sequential span.

Overall, Digits Backward and Digits Forward appear to have factorial similarities, at least

TABLE 3
Three-Factor Promax Solution[a,b]

	Factor		
Subtest	1st	2nd	3rd
Memory for Stories	.05	*.38*	.25
Word Selective Reminding	.10	*.70*	.12
Object Recall	.08	*.58*	.00
Digits Forward	*.78*	.05	.11
Paired Recall	.00	*.66*	.00
Letters Forward[c]	*.82*	.00	.06
Digits Backward[c]	*.51*	.01	.28
Letters Backward	*.55*	.06	.34
Facial Memory	.08	*.43*	.16
Visual Selective Reminding	.02	*.39*	.22
Abstract Visual Memory	.02	*.40*	.35
Visual Sequential Memory	.27	.33	.05
Memory for Location	.02	.02	*.43*
Manual Imitation[c]	*.45*	.04	.28

[a]From Reynolds and Bigler (1996).
[b]Loadings above .35 are italicized.
[c]Supplementary subtest.

with regard to their sequential character. Nevertheless, they also differ as noted above, and the literature suggests the differences have important diagnostic and neurologic implications. Factor analysis of children's TOMAL performance suggests that Digits Backward may require visuospatial processing not needed for Digits Forward. Yet Digits Backward also differs from purely visuospatial measures. Ramsay and Reynolds (in press) argue the distinction may lie in a transformation (Jensen, 1980; Jensen & Figueroa, 1975), which would allow an examinee to shift from verbal to visual processing. The four-factor solution, which best fits the data, is the most strongly suggestive of a distinct backwards recall factor.The dimensionality of the factors when all 14 measures are included is complex and varies across other marker variables. While the inclusion of the many, varied memory tasks on the TOMAL helps clarify some interpretations, the use of only sequential measures may clarify the nature of these specific tasks. Additional analysis may thus prove useful in determining the viability of forward and backward recall as distinct or at least separable tasks that provide more clinically meaningful information viewed apart than when summed or collapsed.

THE CURRENT STUDY

The prior TOMAL analyses included all 14 subtests of that battery. The variables input to a factor analysis influence various outcomes including the number of factors and the strength of various factors. Including all 14 subtests provides information not otherwise available in the correlates and meaning of some subtests. However, the issue of separate forward and backward sequential memory span remains open.

The TOMAL has six different sequential recall tasks, four forward ordered (Digits Forward, Letters Forward, Visual Sequential Memory, and Manual Imitation) and two backward ordered (Digits Backward and Letters Backward). An examination of these sequential recall tasks (described in Table 1 and in Reynolds & Bigler, 1994a, in greater detail) independent of other measures of memory may prove useful in determining whether backward and forward recall tasks should be combined into a single score. New analyses are presented below examining these subtests and the two digit recall and letter recall subtests to determine whether multiple factors are present and if so whether they conform to a forward-backward division.

Subjects

Subjects for the current study consisted of the standardization sample of 1,342 individuals tested to develop the normative tables for the TOMAL. This sample ranges from age 5 years, 0 months, 0 days to 19 years, 11 months, 30 days. The TOMAL sample was stratified on the basis of estimates of the 1990 United States Census and later corrected on the basis of updated reports through 1992. Based on these census estimates, the desired proportions of individuals in various demographic categories were determined. Population proportionate sampling was used to ensure the representatives of the norms relative to the general, normal population of the United States. The demographic characteristics considered in deriving the population porportionate sampling plan included age, gender, ethnicity, socioeconomic status, geographic region of residence, and urban/rural residence. Tables 4 and 5 provide more extensive details regarding the characteristics of the sample of 1,342 children that were taken from 17 states including California, Colorado, Florida, Georgia, Maine, Maryland, Massachusetts, Michigan, Minnesota, New Hampshire, New York, North Carolina, Ohio,

TABLE 4
Demographic Characteristics of the Normative Sample

Characteristic	Percentage of Sample (Weighted)	Percentage of School-Aged Children in U.S. Census
Gender		
Male	50.1	51.2
Female	49.9	48.8
Race		
White	82.6	80.1
Black	12.9	15.7
Other	4.5	4.2
Ethnicity		
Anglo/European	73.2	70.9
African-American	12.5	14.1
Hispanic	9.7	10.6
Oriental/Pacific Islander	2.5	3.3
Native American	2.0	1.1
Geographic Region		
Northeast	18.3	18.7
North Central	22.9	24.4
South	37.9	35.5
West	20.9	21.4
Age (Number of cases)		
Five (82)		
Six (89)		
Seven (137)		
Eight (103)		
Nine (111)		
Ten (157)		
Eleven (163)		
Twelve (116)		
Thirteen (84)		
Fourteen (69)		
Fifteen (52)		
Sixteen (44)		
Seventeen (48)		
Eighteen (42)		
Nineteen (45)		

Pennyslvania, Texas, Utah, and Washington. This is the sample used in the analyses of Reynolds and Bigler (1996) and is described in more detail in Reynolds and Bigler (1994a).

Instrument

The six sequential recall tasks of the TOMAL (from a total of 14 memory tasks) were included and are listed above and described in Table 1. Performance on these six subtests is highly reliable as the median internal consistency reliability estimate ranges from .92 to .97 across tasks (Reynolds & Bigler, 1994a, Table 5.1); reliability estimates in this range are considered to be quite good when associated with lengthy scales and are considered to be excellent for subtests of a larger scale. Such high reliability values also add to the stability of factor analytic and other research results as they are associated with smaller correlated error variances and are less likely to evince spurious relationships.

TABLE 5
Stratification by Age Interval of Selected Sample Characteristics for Unweighted Sample

Geographic Region and Age

	Northeast		North Central		South		West	
Age Interval	*N*	%	*N*	%	*N*	%	*N*	%
5–7	45	14.6	75	24.4	117	38.0	71	23.0
8–10	60	16.2	80	21.6	142	38.3	89	24.0
11–13	81	22.3	77	21.2	140	38.6	65	17.9
14–16	35	21.2	44	26.7	57	34.5	29	17.6
17–19	25	18.5	31	23.0	53	39.3	26	19.3
Total	246	18.3	307	22.9	509	37.9	280	20.9
School Age Population		18.7		24.4		35.5		.21.4

Gender and Age

	Male		Female	
Age interval	*N*	%	*N*	%
5–7	163	52.9	145	47.1
8–10	193	52.0	178	48.0
11–13	172	47.4	191	52.6
14–16	78	47.3	87	52.7
17–19	66	48.9	69	51.1
Total	672	50.1	670	49.9
School Age Population		51.2		48.8

Race and Age

	White		Nonwhite	
Age interval	*N*	%	*N*	%
5–7	248	80.5	60	19.5
8–10	310	83.5	61	16.4
11–13	302	83.2	61	16.8
14–16	137	83.0	28	17.0
17–19	112	83.0	23	17.0
Total	1109	82.6	233	17.4
School Age Population		80.1		19.9

Ethnicity and Age

	Anglo-European		African American		Hispanic		Oriental/Pacific Islander		Native American	
Age interval	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
5–7	220	71.4	44	14.3	28	9.1	8	2.6	8	2.6
8–10	276	74.4	42	11.3	37	10.0	8	2.2	8	2.2
11–13	269	74.1	46	12.7	34	9.4	8	2.2	6	1.7
14–16	123	74.5	20	12.1	14	8.5	6	3.6	2	2.2
17–19	95	70.4	16	11.9	17	12.6	4	3.0	3	2.2
Total	983	73.2	168	12.5	130	9.7	34	2.5	27	2.0
School Age Population		70.4		14.1		10.6		3.3		1.1

Procedure

Two-factor analyses were performed: one analysis with two rotations was performed on the six sequential recall tasks and a cognate analysis using the four tasks that have direct forward and backward analogs (Digits Forward, Digits Backward, Letters Forward, and Letters Backward). In each case the method of principal factors with R^2 as initial community

TABLE 6
Six-Variable Varimax and Promax Two-Factor Solutions of Equential Memory Tasks

	Varimax Solution		Promax Solution	
Subtest	Factor One	Factor Two	Factor One	Factor Two
Digits Forward	.70	.31	.73	.05
Letters Forward	.71	.38	.71	.13
Digits Backward	.32	.67	.06	.71
Letters Backward	.32	.69	.07	.69
Visual Sequential Memory	.42	.20	.43	.04
Manual Imitation	.42	.39	.33	.29

estimates was chosen as the initial method of factoring. Although the large r_{xx} values of the subtests could justify a principal components analysis, a more conservative approach seems in order whenever less than perfect reliabilities are in evidence.

Despite the plethora of factor analytic techniques available, or perhaps because of the many methods available, the choice of an approach remains largely subjective. As a new area of work, exploratory approaches to the data are most appropriate and allow the examination of the similarity of the data across groups as opposed to confirmatory models which (despite their name) tend to focus on differences. There are many procedures available for rotation, and Varimax was chosen as one technique in the current study because it tends to add clarity to the factor structure and maintains independence of the factors derived. However, orthogonal solutions to cognitive structures may be inappropriate since all mental abilities are in fact postively correlated. Promax was chosen then as an oblique procedure for rotation because it has the virtue of approximating simple structure, and it allows the natural intercorrelation of the underlying factors to be seen and to influence the analyses. Promax rotation may also maximize the ability to discriminate among factors, maximizing the variance accounted for by each factor thus adding clarity to the data, intending to produce maximally useful solutions clinically if perhaps of less interest to the theoretical purist. These analyses were undertaken for the six variable and the four variable correlation matrices using the standard algorithms of the 1995 version of SAS, release 6.08.

Results and Discussion Six-variable input.

For all six sequential tasks, a scree plot of initial Eigenvalues suggested one- and two-factor solutions as reasonable. In accord with the theoretical premise of the study a two-factor solution was obtained. Table 6 presents the Varimax and the Promax rotated solutions. In both cases it is clear that the forward and backward recall tasks form two factors. Manual Imitation is the only task to load nearly equally on the two tasks arguing for the salience of imagery on this task, a finding echoed in the results of analyses of the K-ABC where a similar task (Hand Movements) shifts from high loadings on a sequential scale below age 5 years to a simultaneous scale at older ages (see Kamphaus & Reynolds, 1987, for a review and discussion). The Promax solution is the most distinctive of the two solutions but both argue strongly for a two-factor interpretation of these six tasks as forward recall and backward recall. Four-variable input.

When the four most similar tasks, except for order of recall (forward versus backward), are examined, the initial scree plot once again suggest both one and two-factor solutions as appropriate. In accord with the theoretical premise of the study, a two-factor solution was

TABLE 7
Four-Variable Varimax and Promax Two-Factor Solutions of Sequential Memory Tasks

	Varimax Solution		Promax Solution	
Subtest	Factor One	Factor Two	Factor One	Factor Two
Digits Forward	.70	.31	.73	.04
Letters Forward	.70	.38	.71	.12
Digits Backward	.32	.66	.09	.68
Letters Backward	.33	.67	.09	.69

obtained. Table 7 presents the Varimax and Promax rotated solutions. There is no mistaking the clarity of the patterns evident in these loadings. The two forward memory span tasks clearly break apart from the backward memory span tasks, with the promax solution once again being the most distinctive.

These patterns are clearly evident in the correlation matrix for the digit span and letter span tasks seen in Table 8. Digits Forward correlates at a statistically significantly higher level ($p < .001$) with Letters Forward ($r = .70$) than with Digits Backwards ($r = .44$). Digits Forward correlates about equally well with Letters Backwards ($r = .43$). Digits Backwards correlates at a statistically significantly higher level ($p < .001$) with Letters Backwards ($r = .65$) than with Letters Forward ($r = .47$).

Based on these correlations, it is known that 25–30% of normal children will show at least a 1 standard deviation (3 scaled score points) difference between their scores on Digits Forwards versus Digits Backward and on Letters Forward versus Letters Backward. Nearly half of a normal sample will show a scaled score difference of 2 or more points. Thus, statistically significant differences in forward and backward memory span are relatively common in scaled score terms and should not be over interpreted when scaled separately just as they should not be ignored by simply viewing a composite of forward and backward memory span as the difference in the two is potentially informative for many patients, especially those with TBI or CHI. Aging effects in the two measures also could be studied profitably.

When the current results are considered in the context of the theoretical papers reviewed earlier, the work of Jensen (1980; Jensen & Figueroa, 1975), Kaufman and Kaufman (1983), the studies of neurologic patients reviewed earlier in this paper, and the review and reanalyses of Ramsay and Reynolds (in press), there seems to be little justification for continuing the practice of summing raw scores on forward and backward memory span tasks. Indeed, this practice is clearly not necessary to enhance reliability of the measurement as might be argued. Reynolds and Bigler (1994a) report reliability coefficients (coefficients alpha) for the six tasks noted above of greater than .92. Collapsing these variables routinely without making

TABLE 8
Zero-Order Pearson Correlations for Digits and Letters Forwards and Backwards

	Letters Forward	Digits Backwards	Letters Backwards
Digits Forward	.70	.44	.43
Letters Forward		.47	.50
Digits Backward			.65

separate scores available is likely to mask useful information as is clear from the clinical studies of patients reviewed but also now in multiple factor analytic studies (e.g., Reynolds & Bigler, 1996; Woodward et al., 1987) of large samples of normal individuals. This break between forward and backward memory span is enhanced in certain minority populations as well (e.g., Jensen & Figueroa, 1975; Mayfield & Reynolds, 1995).

While combining forward and backward memory span may be useful at times (e.g., de Jong & Das Smaal, 1993; Smyth & Scholey, 1994; Vanderploeg, Schinka, & Retzlaff, 1994) the evidence now seems overwhelming that separate scaled scores for forward and for backward memory span tasks should be provided routinely on any standardized assessment. This practice will facilitate clinical practice and research applications concerning the differential meaning of performance on the two tasks. Current evidence seems to support forward span tasks as being simpler, perhaps verbally oriented, and strongly sequential while backward memory span invokes more complex processes that require transformations not necessary with forward memory span. Backward recall may also invoke, for many individuals, visuospatial imaging processes even for ostensibly verbal material such as letters. Potential differences in the attentional demands or components of these two types of tasks deserves additional study as well. Forward memory span measures may have a stronger attentional component than backward recall measures, which are more highly correlated with general intelligence and require cognitive transformation, an element missing from route, forward recall. Surprisingly much remains to be done to understand the distinction between forward and backward memory span and what it means both clinically and to theories of brain-behavior relationships, but it is clear the tasks are sufficiently different to be assessed separately for clinical purposes.

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