Pergamon

Archives of Clinical Neuropsychology 19 (2004) 507–523

Archives of CLINICAL NEUROPSYCHOLOGY

Speed of presentation influences story recall in college students and persons with multiple sclerosis☆

Peter A. Arnett*

Department of Psychology, Penn State University, 522 Bruce V. Moore Bldg., College of the Liberal Arts, University Park, PA 16802-3105, USA

Accepted 29 July 2003

Abstract

Story memory tests are commonly used in clinical neuropsychology. Surprisingly, no guidelines are provided for speed of presentation for two of the most commonly used story memory tests in clinical neuropsychology. The current investigation was designed to explore whether speed of presentation influences recall on the Story subtest from the Rivermead Behavioural Memory Test. Consistent with predictions, college students in Study 1 and multiple sclerosis participants in Study 2 recalled significantly more story elements at immediate recall when the story was presented slow versus fast. This effect, however, was limited to the conditions where the fast story was presented before the slow story. At delayed recall, participants in both studies recalled more story elements in the slow versus fast story independent of presentation conditions. Both studies also revealed that significantly more participants fell in the "impaired" range on immediate recall for the fast story in the condition where it was presented first. Data from these studies show that speed of presentation can substantially alter story recall in a wide range of individuals. It will be important to develop story tests for which speed of presentation is standardized to ensure that erroneous conclusions regarding memory are not drawn about individuals seen in clinical neuropsychological practice.

Keywords: Multiple sclerosis; Memory; Story recall; Presentation speed; Clinical neuropsychology

☆ The multiple sclerosis (MS) data on the Story subtest published in this article were taken from the same sample of MS participants discussed in Higginson, Arnett, and Voss (2000) and Randolph, Arnett, and Higginson (2001). Presented in part at the 19th Annual Meeting of the National Academy of Neuropsychology, San Antonio, TX, November, 1999.

* Tel.: +1-814-863-1733; fax: +1-814-863-7002.

E-mail address: paa6@psu.edu (P.A. Arnett).

0887-6177/$ – see front matter © 2003 National Academy of Neuropsychology.
doi:10.1016/j.acn.2003.07.006

Story recall tests have long been a staple of neuropsychological assessment batteries. For example, the Logical Memory subtest from the Wechsler Memory Scales (WMS-R; WMS-III; Wechsler, 1987, 1997) has been one of the most widely used memory tests in clinical neuropsychology. A similar subtest from the Rivermead Behavioural Memory Test (RBMT; Wilson, Cockburn, & Baddeley, 1985) known as the Story test has seen increased usage in recent years. It is comparable to Logical Memory, except that there are several alternate forms of the test. Surprisingly, no guidelines are provided for presenting these types of story tests at any particular speed. Thus, speed of presentation of the stories remains an unstandardized and uncontrolled variable in memory assessments using these types of tests.

Concern regarding the importance of controlling the speed of presentation of memory materials is not a new one for clinicians and researchers. For example, the 1955 Wechsler Adult Intelligence Scale manual (WAIS; Wechsler, 1955) notes that the digits for Digit Span should be presented at one per second. Nonetheless, there is still no standardized way of presenting these digits in the most recently updated version of the WAIS (WAIS-III; Wechsler, 1997) and it is up to each individual examiner to insure that these presentation guidelines will be followed. If speed of presentation of standard stories used in clinical neuropsychology influences recall, differences in the speed with which examiners present these stories could significantly influence the conclusions that are drawn about the memory functioning of individuals tested. Presumably, slower presentation of stories would facilitate better recall. If the effect of speed of presentation is great enough, examinees could be labeled as “normal” in their memory functioning if administered a story test relatively slowly, but “impaired” if administered the same test comparatively faster. Relatedly, when alternate forms of these tests are used for repeat testing, as is possible with the RBMT, different speeds of administration at the different time points could result in erroneous inferences about any changes observed in performance. With these considerations in mind, the goal of the present study was to systematically manipulate the speed of commonly used story memory tests to evaluate the possibility that speed of presentation may significantly influence the amount of information recalled.

Why might speed of presentation influence recall on story memory tests? Possible explanations may be found in models of word list memory. For instance, both the Adaptive Control of Thought—Rational (ACT-R) model of list learning (Anderson, Bothell, Lebiere, & Matessa, 1998) and the Search of Associative Memory (SAM) model (Raaijmakers & Shiffrin, 1981) give detailed accounts for why longer presentation times lead to better recall of word lists. For both of these models, stronger memory representations are recalled better than weaker ones, and recall is better for those representations with stronger associations to cues used to probe memory. It is reasonable to expect that many of the same factors that underlie ACT-R and SAM’s account of list learning would apply to story recall as well, because both types of tasks involve recall of verbal materials. It may be that extra presentation time allows for the strengthening of the associations between elements of the experimental context and the episodic representation of having studied the story elements. Another possibility is that the extra presentation time allows the representations of the story elements to strengthen. Finally, the extra time may allow the examinee to build up a richer set of connections between story elements, enhancing the ability of one story element to cue the retrieval of another. Although the present study is not designed to test possible mechanisms if the hypothesized results are obtained, some combination of the above possibilities provides a reasonable theoretical underpinning for predicting differential recall in the fast versus slow presentation conditions.

Related to the possibility that speed of story presentation influences recall is the less than optimal reliability that often characterizes story memory tests commonly used in clinical neuropsychology. A decision-consistency methodology was used to evaluate the reliability of the Logical Memory subtests from the WMS-III. This involved dividing subtest scaled scores into ranges and then assessing the consistency of the test-retest classification. The stability coefficients over an average interval of 35.6 days for first recall total score for the 16–54 age group were 66% for Logical Memory I and 64% for Logical Memory II; for the 55–89 age group, these values were 73 and 62%, respectively (The Psychological Corporation, 1997). Thus, even for the most widely used, carefully normed story memory test, the reliability data are relatively poor. Although speculative, one factor that may contribute to the relatively low reliability of story recall tests like Logical Memory is error introduced by differences in rate of story presentation. For the Story subtest from the RBMT, no reliability data are available in either the primary manual or supplement books 2 and 3. The only reliability data reported are for the entire RBMT battery combined, not any individual subtests, so there is no way of evaluating the reliability of the Story subtest with currently available sources. Nonetheless, we used the RBMT Story subtest in the present study because of its alternate forms.

For the current study, two parallel forms of the Story subtest from the RBMT were used. Both forms were given to the same participants, but at different speeds and counterbalanced for order of presentation. It was hypothesized that participants would recall significantly more of the slow story compared with the fast story. A related hypothesis was that significantly more participants would score in the "borderline" or "abnormal" range on the fast compared with the slow story recall. In the first study presented, we tested college students; the second study involved an evaluation of persons with multiple sclerosis (MS).

1. Study 1

1.1. Method

1.1.1. Participants

The Story subtest from the RBMT, in addition to several other neuropsychological tests, was administered to 51 college students who received extra course credit for their participation. All participants reported having normal hearing and vision, and denied any history of a learning disability. Four participants who spoke English as a second language were not included in the data analyses. Thus, data for 47 participants were analyzed.

1.1.2. Measures

1.1.2.1. Story subtest from the Rivermead Behavioural Memory Test (RBMT; Wilson et al., 1985). This test involves the immediate and 20-min delayed free recall of a brief prose passage. Two alternate forms of the stories were presented via audiotape with the same female voice. The American versions of Story B ("Fireman & Volunteers") and Story D ("Dutch Oil Tanker") were used. Each story presents 21 ideas, with 56 words included in Story B and 54 in Story D.

Cockburn, Baddeley, and Hiorns (1989) report correlations in the .80s between Profile Scores for form A and forms B, C, and D from the RBMT. Although forms B and D, from which the current stories were taken, were never compared directly, their similar correlations with form A suggest that they are likely to be reasonably equivalent. The presentation of the stories was counterbalanced with two orders and two different speeds. Thus, four orders were used for story presentations, providing complete counterbalancing of presentation. Slow stories were presented at a rate of 39 s from beginning to end; fast stories were presented at a rate of 17 s. These speeds correspond to speaking rates of 85 words per minute (wpm) and 190 wpm, respectively. This speed of presentation difference was the primary experimental manipulation in the study. The story speeds were selected so that the fast story sounded qualitatively like moderately fast conversational speech and the slow story sounded like slower than normal conversational speech. These estimations were informally arrived at based on the perceptions of the author and lab assistants running participants for the study and did not change over the course of the study. Walker's (1988) study provides a reference point for these speeds. This investigator found that reading speed for a standard reading passage was approximately 188 wpm. This corresponds closely to the fast condition for the present study. Walker also notes that conversational speech is somewhat slower than this reading speed, with the mean of her sample being about 173 wpm.

The primary scoring index for the stories was the total number of story ideas recalled. An additional standard scoring index was calculated based on procedures outlined in the RBMT Supplement Two manual (Wilson, Cockburn, Baddeley, & Hiorns, 1991). Specifically, total immediate recall scores of 6 or more were given standard scores of 2 (normal), scores of 4–5.5 given standard scores of 1 (borderline), and scores less than 4 given standard scores of 0 (abnormal). The corresponding values for the total delayed recall were: 4, 2–3.5, and less than 2, respectively.

1.1.2.2. Current estimate of intellectual functioning (Zachary, 1986). Current intellectual functioning was estimated from the Vocabulary subscale of the Shipley Institute of Living Scale.

1.1.3. Procedure

Participants were tested individually and received one of the four possible orders of Story subtest presentation. Each order involved the recall of two Story subtest stories at immediate and delayed recall. In every order, immediate recall for the second story was always presented after the delayed recall of the first story. Two questionnaires and several other neuropsychological tests were also administered. During the delay intervals, all participants performed the same tasks in every order. These tasks involved visual-spatial neuropsychological tasks, questionnaires, and a measure of intellectual functioning. Participants were not given any guidelines regarding what they should do visually while stories were presented, but the testing room was free of visual clutter to minimize possible distractions. One of two experimenters administered all tests for each subject.

1.1.4. Statistical analyses

One-way Analyses of Variance (ANOVAs), with test order as the grouping variable and one of the four recalls (2 immediate, 2 delay) as the dependent variable in successive analyses, were conducted to evaluate possible order and story content effects. One-way ANOVAs, with experimenter as the grouping variable and one of the four recalls (2 immediate, 2 delay) as the dependent variable in successive analyses, were conducted to evaluate possible experimenter effects.

The primary hypothesis-testing analyses involved mixed-model ANOVAs with Story Speed as the within groups factor (recall for slow story, and recall for fast story) and Order as the between groups factor (fast story first and slow story second, slow story first and fast story second). Separate analyses were conducted for immediate and delayed recall. Another hypothesis-testing analysis involved using Cochran's Test for Related Observations (Conover, 1980) to evaluate the number of participants who would be screened as "borderline" or "abnormal" versus "normal" on the fast versus slow story using the RBMT screening score.

1.2. Results

1.2.1. Preliminary data evaluation

Participant characteristics are outlined in Table 1. As shown, the participants administered the four different orders did not differ significantly on any participant variable. Additionally, one-way ANOVAs conducted to examine possible effects of test order combined with story content on recall of immediate and delayed stories revealed no statistically significant effects (all P-levels for the four omnibus $F\text{s}(3, 43) > .05$). These analyses show that, overall, the participant groups administered the different orders did not differ in their recall of fast or slow stories for immediate or delayed recall. Therefore, we combined the two subject groups getting the fast story first and the slow story second, and separately combined the two subject groups administered the slow story first and the fast story second and conducted the two mixed-model ANOVAs described earlier for the hypothesis-testing analyses. Similarly, no significant effects were found for the analysis of experimenter effects, (all P-levels for the four $F\text{s}(1, 45) > .05$). As a result, data were collapsed across experimenter for all analyses.

Table 1
Characteristics for college student participants by test order

Variable	Order A	Order B	Order C	Order D	$F(3, 43)$	P-value
n	12	12	12	11		
Age	20.4 (1.8)	20.2 (1.5)	19.4 (1.4)	21.0 (1.3)	2.15	ns
Shipley Vocabulary	56.7 (5.2)	53.3 (5.5)	57.3 (6.7)	55.3 (7.0)	<1.0	ns
	n (%)	n (%)	n (%)	n (%)	χ^2	
Race					<1.0	ns
Caucasian	10 (83)	11 (92)	11 (92)	10 (91)		
African-American	1 (8)	0 (0)	0 (0)	0 (0)		
Latino/Latina	0 (0)	0 (0)	1 (8)	0 (0)		
Asian	1 (8)	0 (0)	0 (0)	1 (9)		
Other	0 (0)	1 (8)	0 (0)	0 (0)		
Sex (females)	10 (83)	9 (75)	11 (92)	11 (100)	3.60	ns

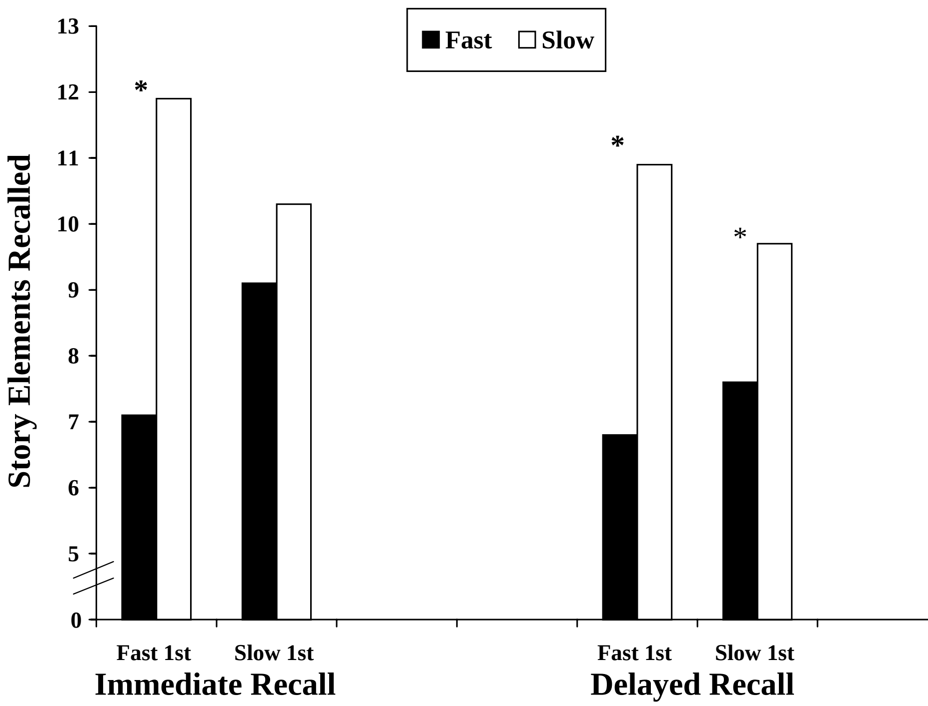

Fig. 1. Story elements recalled for fast and slow story presentation, Study 1, college student data. Fast first: group administered the fast story first and the slow story second; slow first: group administered the slow story first and the fast story second. Asterisks denote statistically significant differences between immediately adjacent bars below based on Tukey B HSD post hoc test.

1.2.2. Hypothesis-testing analyses

For the ANOVA examining immediate recall of the stories, a significant main effect for Order × Story was found [$F(1, 45) = 32.40$, $P < .001$]. Consistent with predictions, participants recalled significantly more story elements when the story was presented slow versus fast (see Fig. 1). However, this significant main effect was qualified by a significant Story Speed × Order interaction [$F(1, 45) = 9.64$, $P < .005$]. Tukey-B HSD post hoc tests revealed that this interaction was primarily due to the effect of Order on fast story recall. When participants were administered the fast story first, consistent with hypotheses they recalled significantly ($P < .05$) fewer story elements on the fast compared with the slow story. When they were administered the slow story first, in contrast to predictions participants did not differ significantly on their recall of the slow versus fast story. The Tukey tests also revealed that, when participants were compared on the slow versus fast stories both presented first across orders, the group getting the fast story first recalled significantly less than the group getting the slow story first.

For the ANOVA examining delayed recall of the stories, a significant main effect for Order × Story was again found [$F(1, 45) = 27.62$, $P < .001$]. Consistent with predictions and similar to the results for immediate recall, participants recalled significantly more story elements

Table 2
Proportion and percentage of college students in different orders scoring in the impaired range on the RBMT Story subtest

	Order 1 (slow first, fast second) ($n = 23$)			Order 2 (fast first, slow second) ($n = 24$)		
Variable	n (%)	$Q(1, N = 23)$	P	n (%)	$Q(1, N = 24)$	P
Fast, immediate	2 (9)			9 (38)		
Slow, immediate	1 (4)	<1.0	ns	3 (13)	4.50	<.05
Fast, delayed	2 (9)			4 (17)		
Slow, delayed	0 (0)	2.0	ns	2 (8)	<1.0	ns

Note. RBMT: Rivermead Behavioural Memory Test. Impairment defined as scoring in either the "borderline" or "abnormal" range on calculation of the standard scoring index outlined by Wilson et al. (1991). "Q" refers to Cochran's Q.

when the story was presented slow versus fast. The Story Speed × Order interaction was not significant [$F(1, 45) = 1.63$, ns]. Thus, for delayed recall, the effect of presentation order was negligible compared with immediate recall.

The next set of hypothesis-testing analyses compared the number of "borderline" and "abnormal" scores (collectively referred to as "impaired") versus "unimpaired" for participants' scores on the slow versus fast stories. Because of the order effects just described, these results are presented separately for the two collapsed orders for immediate recall. As Table 2 illustrates, the effect of Order × Story on immediate recall was seen only in the order where the fast story was presented first. In this order, consistent with predictions, significantly more participants scored in the impaired versus unimpaired range on the fast compared to slow story on immediate recall [Cochran's $Q(1, 47) = 4.50$, $P < .05$]. In contrast to predictions, no significant differences were found on delayed recall.

1.3. Discussion

Consistent with hypotheses, student participants recalled significantly fewer story bits when the stories were presented fast versus slow at both immediate and delayed recall. Importantly, however, the results for immediate recall were mostly due to the two conditions where the fast story was presented first. As Fig. 1 illustrates, participants recalled almost five more story elements on the slow versus fast story on immediate recall when presented with the fast story first followed by the slow story. When presented with the slow story first followed by the fast story, participants recalled only about 1.5 more story elements on the slow versus fast story. Also consistent with predictions, significantly more participants scored in the impaired range for immediate recall when the story was presented at the fast speed compared with the slow speed. Again, this effect was only evident in the conditions where the fast story was presented first before the slow story and only apparent on immediate recall. Our results suggest that a variable that is typically uncontrolled for in clinical evaluations, rate of presentation, can significantly alter the performance of some high-functioning college students who presumably have at least average memory functioning. This rate of presentation effect is, however, consistently evident only for immediate recall in situations where a story read slightly faster than normal conversational speech (but comparable to normal reading speed) is the first story presented.

Study 2 is presented to examine the generalizability of our results to a clinical sample of individuals for whom problems with verbal recall and processing speed are common: persons with MS (Arnett, 2003; Benedict et al., 2002). Although the results of Study 1 are illuminating, they are not directly pertinent to clinical neuropsychological work because the sample was not comprised of neurological patients with known cognitive problems in verbal recall and processing speed. To our knowledge, there are no MS studies where the effect of speed of information presentation on recall has been systematically evaluated. Relatedly, however, Demaree, DeLuca, Gaudino, and Diamond (1999) found that persons with MS improved their accuracy to the level of controls when they performed a speeded working memory test like the Paced Auditory Serial Addition Test (PASAT) at an optimum (slower than controls) interstimulus interval. The same phenomenon may occur for memory recall. Because not all persons with MS display memory difficulties, the data for Study 2 will also be examined in a subset of MS participants who show clear evidence of significant memory problems based on their performance on a standard clinical memory test, the California Verbal Learning Test (CVLT; Delis, Kramer, Kaplan, & Ober, 1987). It was hypothesized that even these MS participants with significant recall memory problems would show better performance on the slow presentation of the Story subtest compared with the fast presentation. If this hypothesis is supported, our data will suggest that even participants with verbal recall memory problems can benefit on recall from a slower presentation of information.

2. Study 2

2.1. Method

2.1.1. Participants

Seventy-nine Caucasian MS participants were administered a comprehensive neuropsychological battery, however, the first three participants in the study were not administered the story task. The first three participants in the study were not administered the Story task. Following testing, it became known that one patient had been comatose for an extended period of time in childhood following an allergic reaction. Another patient refused or was unable to complete a large portion of the test battery. Excluding these subjects, a total of 74 participants had valid data for immediate and delayed recall for one fast and one slow Story subtest.

The MS participants were recruited from neurologists and support groups in the Northwestern United States. Participants were excluded if, based on their self-report, they: (a) had a history of alcohol/drug abuse or nervous system disorder other than MS; (b) had severe motor or visual impairment that might interfere with cognitive testing; (c) had a premorbid history of a learning disability; (d) could not easily be evaluated at our university because of severe physical/neurological impairment; or (e) did not live within a convenient distance to one of our testing centers.

All participants received an extensive neuropsychological evaluation as part of an ongoing longitudinal study of cognitive and emotional functioning in MS. Each MS participant was diagnosed as having definite or probable MS based on Poser et al. (1983) criteria by a board-certified neurologist who also determined disease course using Lublin and Reingold (1996) criteria. Duration of illness from symptom onset and from diagnosis, and neurological disability (Expanded Disability Status Scale [EDSS]; Kurtzke, 1983) were also assessed. None of the MS participants included in the current study were experiencing a clinical exacerbation at the time of the evaluation. This was determined by asking participants if they were currently experiencing an exacerbation or worsening of their symptoms. All participants were provided with a written neuropsychological screening evaluation and verbal feedback in return for their participation, gave informed consent according to institutional guidelines, and were treated in accordance with the ethical standards of the APA.

2.1.2. Measures

Immediate and delayed recall of one fast and one slow story from the Story subtest of the RBMT were included and presented via audiotape by a male voice. One difference from the first study in Story subtest presentation was that only a slow presentation of the American version of Story B and a fast presentation of the American version of Story D were used. However, like Study 1, the presentation of fast versus slow stories was counterbalanced so that approximately half of the participants received the fast story first and the slow story second and the other half received the *slow* story first and the fast second. The Vocabulary subscale from the Shipley (Zachary, 1986) was also included as an estimate of verbal intellectual functioning.

To address issues of clinical relevance (described earlier and below), a verbal list-learning measure, the California Verbal Learning Test (CVLT; Delis et al., 1987), was assessed in Study 2. The CVLT is a word list-learning task involving the free recall of a 16-item word list across five trials. The words are organized into four semantic categories, but examinees are not told this at the outset. Following the initial five trials, there is an interference trial and then immediate and delayed (20 min) free and cued recall trials followed by a recognition test. Total correct across Trials 1–5 was used as the dependent measure. Although the CVLT has been used infrequently in MS research studies, word list tasks such as the verbal Selective Reminding Test have been commonly implemented (e.g., Rao, Leo, Bernardin, et al., 1991).

Because high levels of mood and evaluative symptoms of depression have been shown to be associated with some effortful cognitive functions in MS (Arnett, Higginson, & Randolph, 2001; Arnett, Higginson, Voss, Bender, et al., 1999; Arnett, Higginson, Voss, Randolph, & Grandey, 2002; Arnett, Higginson, Voss, Wright, et al., 1999), mood and evaluative symptoms of depression were assessed using the mood and evaluative subscales from Nyenhuis et al.'s (1995) Chicago Multiscale Depression Inventory (CMDI). This self-report questionnaire was specifically designed for use in MS and other medical patient groups and has mood, evaluative, and vegetative subscales consisting of 14 items each. Examinees are asked to rate on a scale of 1 to 5 the extent to which each word or phrase describes them during the past week, including today, where 1 is "Not at All" and 5 is "Extremely." We simply evaluated any possible order group differences on the evaluative and mood subscales to insure that any group differences we observed could not be attributed to possible differences in these aspects of depression. Because the CMDI is a relatively new measure, depression was also assessed with the Beck Depression Inventory (BDI; Beck & Steer, 1987).

2.1.3. Procedure

The 74 participants were tested individually and received one of the two possible orders of Story subtest presentation. Each order involved the recall of two Story subtest stories (one fast, one slow) at immediate and delayed recall. Participants' involvement in this study was much more extensive than for those in Study 1; between 4 and 6 h of testing were completed for Study 2 compared with about 1 hour for Study 1. During the delay intervals, participants either performed visual-spatial neuropsychological tasks, a span task, other subtests from the RBMT, or completed questionnaires. Activities included in the interval differed slightly from one order to the next within this study and also compared with Study 1. In each order, immediate recall for the second story was always presented after the delayed recall of the first story. As with Study 1, participants were not given any guidelines regarding what they should do visually while stories were presented, but the testing room was free of visual clutter to minimize possible distractions. One of four experimenters administered all tests for each subject.

2.1.4. Statistical analyses

All analyses conducted for Study 1 were used in Study 2 with the exception that, because only two test orders were used, the preliminary analysis examining possible effects for story content combined with order were unnecessary. As a result, order effects could be examined in the context of the mixed-model ANOVAs used for the hypothesis-testing analyses.

An additional set of analyses were conducted in Study 2 to address an issue of clinical significance. These analyses were designed to examine whether even participants with significant recall memory problems on another commonly used clinical neuropsychological verbal memory test, the CVLT, would show better performance on the Story subtest if it was presented slow versus fast. Participants with memory dysfunction were defined as those with scores less than or equal to 11/2 S.D. below the mean of the normative sample (*t* score less than or equal to 35) on total correct recall for Trials 1–5 on the CVLT.

2.2. Results

2.2.1. Preliminary data evaluation

Participant characteristics are outlined in Table 3. As shown, the participants administered the two different orders did not differ significantly on any participant variable. Additionally, none of the analyses evaluating possible experimenter effects were statistically significant [all P-levels for the four Fs$(3, 70) > .05$]. As a result, data were collapsed across experimenter for all analyses.

2.2.2. Hypothesis-testing analyses

Consistent with predictions, the mixed-model ANOVA revealed a significant main effect for Order $\times$ Story [$F(1, 72) = 43.63$, $P < .001$] with participants recalling more story elements on immediate recall when presented the slow versus fast story. However, comparable to Study 1, this main effect was qualified by a significant Order $\times$ Story Speed interaction [$F(1, 72) = 5.36$, $P < .05$]. As with Study 1, Tukey-B HSD post hoc tests revealed that this interaction was primarily due to the effect of order on fast story recall. When participants were administered the fast story first, consistent with hypotheses they recalled significantly

Table 3
Characteristics of multiple sclerosis participants by order

Variable	Order 1 (slow first)	Order 2 (fast first)	$t(72)$	P-value
n	38	36		
Age	46.7 (7.9)	46.6 (8.7)	0.04	ns
Education	15.1 (2.1)	14.7 (2.7)	0.74	ns
Premorbid IQ estimate	108.8 (5.7)	107.7 (6.3)	0.81	ns
Shipley Vocabulary	55.9 (6.0)	53.3 (7.3)	1.70	ns
EDSS (Kurtzke, 1983)	4.7 (1.5)	4.7 (1.3)	−0.29	ns
Symptom duration (years)	13.8 (9.5)	15.1 (10.7)	−0.55	ns
Diagnosis duration (years)	8.1 (8.4)	7.8 (7.5)	0.18	ns
CMDI Mood Scale	22.5 (9.6)	21.9 (6.9)	0.31	ns
CMDI Evaluative Scale	20.8 (9.6)	18.5 (5.3)	1.24	ns
BDI	11.8 (9.0)	10.3 (6.9)	0.79	ns
			$\chi^2(1, N = 74)$	
Medications with cognitive effects	16/38 (42%)	12/36 (33%)	0.61	ns
Sex, n (% female)	32/38 (84)	27/36 (75)	0.97	ns
Diagnostic category			5.19	ns
Clinically definite, n (%)	31/38 (82)	35/36 (97)		
Laboratory definite, n (%)	3/38 (8)	1/36 (3)		
Clinically probable, n (%)	3/38 (8)	0/36 (0)		
Laboratory probable, n (%)	1/38 (3)	0/36 (0)		
Clinical course			0.11	ns
Relapsing-remitting, n (%)	23/38 (61)	22/36 (61)		
Primary progressive, n (%)	4/38 (11)	3/36 (8)		
Secondary progressive, n (%)	10/38 (26)	10/36 (28)		
Progressive relapsing, n (%)	1/38 (3)	1/36 (3)		

Note. Values for t-test analyses represent means (S.D.). CMDI: Chicago Multiscale Depression Inventory; BDI: Beck Depression Inventory; EDSS: Expanded Disability Status Scale. For χ^2 analyses, d.f. = 1, $N = 74$ for medications and sex, and d.f. = 3, $N = 74$ for diagnostic category and clinical course.

($P < .05$) fewer story elements on the fast compared with the slow story. When they were administered the slow story first, in contrast to predictions participants did not differ significantly on their recall of the slow versus fast story. As illustrated in Fig. 2, participants recalled almost four additional story elements on the slow compared with fast story in order 2 where the fast story was presented first, but slightly less than two more story elements in order 1 where the fast story was presented second. The Tukey tests also revealed that, comparable to Study 1, when participants were compared on the slow versus fast stories both presented first across orders, the group getting the fast story first recalled significantly less than the group getting the slow story first.

For delayed recall of the stories, a significant main effect for Story Speed was found [$F(1, 72) = 55.10$, $P < .001$]. Consistent with predictions and similar to Study 1 and the results for immediate recall, participants recalled significantly more story elements when the story was presented slow versus fast. The Story Speed × Order interaction was not statistically significant [$F(1, 72) = 2.09$, ns]. Thus, again similar to Study 1 for delayed recall, the effect of presentation order was negligible compared with immediate recall.

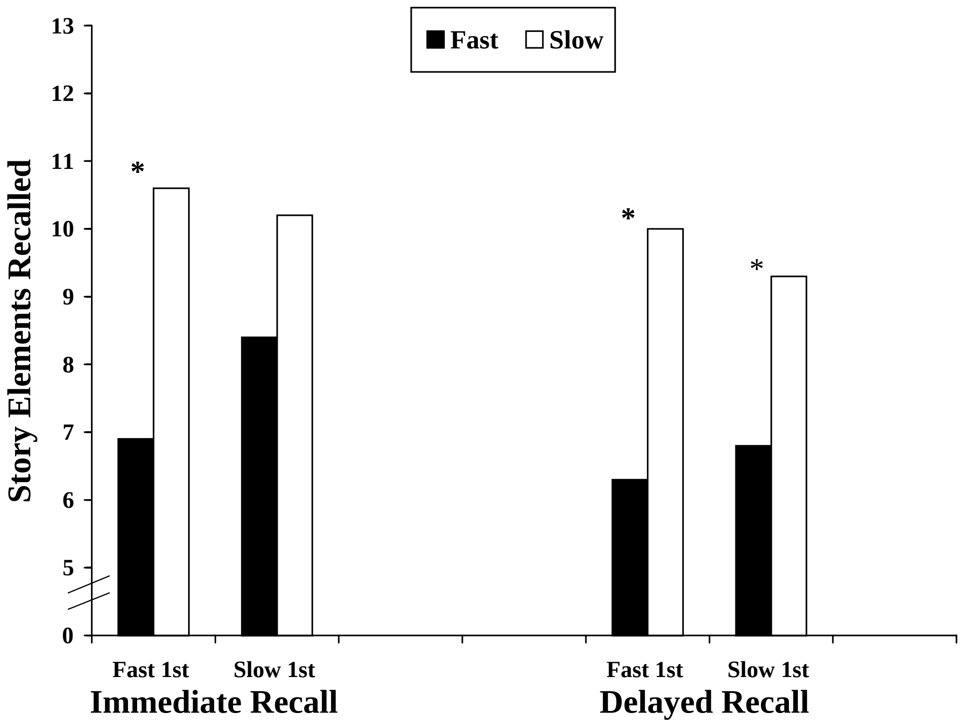

Fig. 2. Story elements recalled for fast and slow story presentation, Study 2, multiple sclerosis participant data. Fast first: group administered the fast story first and the slow story second; slow first: group administered the slow story first and the fast story second. Asterisks denote statistically significant differences between immediately adjacent bars below based on Tukey B HSD post hoc test.

The next set of hypothesis-testing analyses compared the number of "borderline" and "abnormal" ("impaired") versus unimpaired for participants' scores on the slow versus fast stories. Again, because of the significant order differences found, data for each order were analyzed separately. As Table 4 illustrates, like Study 1, the effect of Order × Story was seen

Table 4
Proportion and percentage of multiple sclerosis participants in different orders scoring in the impaired range on the Story subtest

	Order 1 (slow first, fast second) ($n = 38$)			Order 2 (fast first, slow second) ($n = 36$)		
Variable	n (%)	$Q(1, N = 38)$	P	n (%)	$Q(1, N = 36)$	P
Fast, immediate	5 (13)			10 (28)		
Slow, immediate	3 (8)	<1.0	ns	3 (8)	4.46	<.05
Fast, delayed	3 (8)			4 (11)		
Slow, delayed	2 (5)	<1.0	ns	3 (8)	<1.0	ns

Note. RBMT: Rivermead Behavioural Memory Test. Impairment defined as scoring in either the "borderline" or "abnormal" range on calculation of the standard scoring index outlined by Wilson et al. (1991). "Q" refers to Cochran's Q.

for immediate recall only in the order where the fast story was presented first. In this order, significantly more participants scored in the impaired range on the fast compared to slow story, but only on immediate recall [Cochran's $Q(1, 74) = 4.46$, $P < .05$].

The final set of analyses addressed another aspect of clinical relevance using the CVLT. Eighteen participants were identified with scores for total recall, Trials 1–5, less than or equal to a *t* score of 35 based on normative data. This cut-off was chosen because participants at or below it would fall in the "borderline" range on the test or below (Spreen & Strauss, 1998, p. 27). By examining only those participants with documented difficulty with memory based upon performance on another verbal memory test, we evaluated whether even examinees with some documented verbal memory difficulties would be able to benefit from slower story speed presentation. Such a demonstration could have significant implications for helping memory-impaired persons with MS develop memory enhancement strategies. Because of the small sample size and because twice as many participants ($n = 12$ vs. $n = 6$) in this subsample received the order where the slow story was administered first, we combined subjects across orders and conducted a paired samples *t* test for both immediate and delayed recall. Comparable to the pattern for the college students and MS participants as a whole, the CVLT memory-impaired participants recalled significantly more story items on immediate recall when the story was presented slow versus fast [$t(17) = -3.61$, $P < .005$, Cohen's $d = .95$]. Results were similar for delayed recall [$t(17) = -2.76$, $P < .02$, Cohen's $d = .87$]. Both effect sizes fall in the "large" range according to Cohen (1988).

2.3. Discussion

Consistent with predictions and comparable to college student data from Study 1, MS participants recalled significantly fewer story elements when the stories were presented fast versus slow at immediate recall. Again in contrast to expectations, this effect was only found in the order where the fast story preceded the slow story. In the other order, MS participants did not differ significantly in their recall of the fast versus slow stories. Consistent with hypotheses and the results from Study 1, this effect of story order was not found on delayed recall; MS participants recalled significantly fewer story elements with the fast story versus the slow story regardless of order.

Also consistent with expectations and with Study 1, significantly more participants scored in the impaired range on the fast versus slow stories, but this was only true for immediate recall. Again unexpectedly, this effect was found only in the order where the fast story was presented first. An additional finding from Study 2 was that even MS participants with significant verbal memory recall problems benefitted significantly in their recall from slowed story presentation.

3. General discussion

The symmetry to the results across both of the studies presented is informative. Despite vast differences in the samples between the studies in terms of age and neurological status, the pattern of results across studies was nearly identical: First presentation of a story test in moderately fast conversational speech resulted in significantly less immediate recall than a story test in slower speech in both college students and persons with MS. Additionally, significantly more examinees from both college student and MS samples scored in the impaired range on immediate recall when the relatively faster story was presented before the slower story. These results suggest that an uncontrolled variable, rate of presentation, can significantly alter the performance of a wide range of examinees on story recall tests.

Given that the results reported were highly replicable across very different sample groups, they strongly suggest that better standardization of the rate of presentation will be necessary to insure greater accuracy of story memory test results, especially the RBMT. Additionally, given that the more widely used Logical Memory subtests from the Wechsler Memory Scale are analogous to the RBMT stories, the current results may have implications for these tests as well. Despite the fact that the WMS was recently re-normed with a large and highly representative national sample, the results from the current studies indicate that potentially erroneous conclusions can be drawn about the memory functioning of examinees if attention is not paid to rate of story presentation. A reasonable best solution would be to develop better standardization of story tests via the audio-taped or computerized presentation of stories at a standard speed.

Beyond reducing error in story test scores as well in clinical interpretation of the results, presentation of such tests at standardized speeds has other advantages. Developing standardized story and possibly other verbal memory tests presented at different speeds might be clinically useful in helping to evaluate the influence of processing speed on verbal memory functioning. Some individuals may benefit more than others from slowing the rate of presentation of verbal materials. Such persons hoping to improve their verbal recall might thus utilize techniques that allow them to slow the intake of verbal information and thus improve their everyday memory functioning. Results from our second study suggest that memory-impaired persons with MS can still show better recall of stories when they are presented at slower speeds. The data from this second study also dovetail nicely with the report of Demaree et al. (1999) report that persons with MS improve their accuracy to the level of controls when administered a speeded working memory test like the PASAT at an optimum interstimulus interval. Combined with studies indicating that repetition (DeLuca, Gaudino, Diamond, Christodoulou, & Engel, 1998) and self-generated to-be-remembered information (Donofrio & DeLuca, 2001) facilitates recall in MS, a reasonable plan for rehabilitating memory recall in MS can be designed. When memory-impaired individuals with MS can slow their intake of information, use repetition, and self-generate information they need to remember, they may be most likely improve their recall in everyday situations.

One limitation of the current investigation is that the vast majority of participants in Study 1 and all participants in Study 2 were Caucasian. Although participants across studies differed on many characteristics other than race, suggesting some generality to the findings, sampling constraints preclude generalization across racial groups. Additionally, caution is warranted regarding the full generalization of these findings because a limited range of education and age levels, disorders, disease states, and testing conditions (e.g., bedside vs. controlled lab setting) was examined. Future studies will be necessary to evaluate the generality of the findings to these domains. Another limitation of the present study is that the speech manipulation was based on the subjective perception of the author and his assistants. A better approach for future studies on this topic would be to have these perceptions based on the empirical reports of a wider range of individuals. Nonetheless, as noted earlier, studies on rate of speech suggest that our fast story was presented in slightly faster than normal conversational speech, and the slow story substantially slower than this.

An additional limitation of this investigation is that, on a parameter of considerable neuropsychological significance, delayed recall, no differences in impairment classifications were found for the fast stories versus slow stories across both studies. This was despite extremely large and significant (*F*s of 27.62 and 55.10 for Study 1 and Study 2, respectively) mean differences found between delayed fast versus slow story elements recalled. However, the absence of this finding may have more to do with the extremely low cut-off criterion for “borderline” or “abnormal” performance set for delayed recall on the Story test. As can be seen in Tables 2 and 4 on the delayed recall for both studies when the fast story was presented first, only about half as many participants overall were classified as “borderline” or “abnormal” for delayed compared with immediate recall. In examining Figures 1 and 2, though, it is apparent that when the fast story was presented first, participants’ recall from immediate to delayed recall was almost identical. So, despite no real change in performance on the fast story from immediate to delayed recall for participants presented the fast story first in both studies, the impairment classification changed substantially. Thus, the absence of a difference in impairment classification for delayed recall may have been an artifact of the extremely low cutoff set for impairment rather than a real change in performance.

A final limitation of the present studies is that their design did not allow for an investigation of the possible mechanisms underlying the differential recall caused by the different rates of presentation. Stronger memory representations may have been developed when more time was afforded for story presentation, representations from the story may have developed stronger associations of cues to probe memory, or extra presentation time may have resulted in strengthening the associations between elements of the experimental context and studying the story. Additionally, the longer presentation time may have allowed the representations of the story elements to strengthen, and finally, the extra time may have allowed examinees to develop a richer set of connections between story elements, facilitating recall. A follow-up study could be designed to explore the validity of such possible mechanisms.

In summary, these studies demonstrate a significant influence of speed of story presentation on subsequent recall that is independent of differences in demographic, illness, and memory-impaired features of the individuals tested. The data provide a strong case for better standardization of presentation speed for existing story memory tests used in clinical neuropsychology. Beyond demonstrating mean differences in performance according to speed of presentation, these studies establish clinical utility in at least two realms. First, they show that a significant number of examinees who perform normally at immediate recall when a story is presented relatively slowly will actually be labeled impaired based on their performance on a first-presented relatively fast story. Second, the data also suggest that even verbal memory-impaired persons with MS will significantly improve their story recall when presentation speed is slowed. Combined with other recent work examining techniques that facilitate memory recall in MS, such as self-generation and repetition, the results from the present study add to a small but growing literature suggesting that individuals with MS may be able to improve their recall memory functioning using specific techniques. Given the demonstration by prior research that cognitive deficits can substantially impact the everyday functioning of persons with MS (e.g., Higginson, Arnett, & Voss, 2000; Rao, Leo, Ellington, et al., 1991), clinicians should be aware that there are concrete techniques they can employ that may improve individuals' cognitive functioning, and possibly, their quality of life and ability to function better in their everyday lives.

Acknowledgments

Special thanks to the many neurologists in the Inland Northwest, particularly Drs. William Bender, Jon Tippin, and John Wurst, who contributed their time to verifying MS diagnoses and ratings of course for the MS participants in the project. I would also like to thank Doreen Evans, Diane Wicks, and Lorri Bays for their help with the project in the Spokane area. Additionally, I thank Christopher Higginson, William Voss, John Randolph, Pamela Freske, William Porter, Bruce Wright, Jennifer Geier, Jan Kusch, Eman Ziada, Cindy Eason, Stephanie Pantalone, Molly Riley, Luciano Tristan, Martin Pankiewicz, and Alfred Bagamasbad for their help with various aspects of the project. I also thank Dr. Jeffrey Parker for consultation on statistical issues, and Dr. Lael Schooler for consultation on memory models. Finally, I would especially like to express my gratitude to the MS participants and their significant others who generously contributed their time to helping us better understand the nature of multiple sclerosis and cognitive functioning.

References

Anderson, J. R., Bothell, D., Lebiere, C., & Matessa, M. (1998). An integrated theory of list memory. *Journal of Memory and Language*, *38*, 341–380.

Arnett, P.A. (2003). Neuropsychological presentation and treatment of demyelinating disorders. Invited chapter for the Handbook of Clinical Neuropsychology P. Halligan, U. Kischka, & J. Marshall (Eds.), pp. 528–543, Oxford University Press: Oxford, UK.

Arnett, P. A., Higginson, C. I., & Randolph, J. J. (2001). Depression in multiple sclerosis: Relationship to planning ability. *Journal of the International Neuropsychological Society*, *7*, 665–674.

Arnett, P. A., Higginson, C. H., Voss, W. D., Bender, W. I., Wurst, J. M., & Tippin, J. M. (1999). Depression in multiple sclerosis: Relationship to working memory capacity. *Neuropsychology*, *13*, 546–556.

Arnett, P. A., Higginson, C. I., Voss, W. D., Randolph, J., & Grandey, A. A. (2002). Relationship between coping, depression, and cognitive dysfunction in multiple sclerosis. *The Clinical Neuropsychologist*, *16*, 341–355.

Arnett, P. A., Higginson, C. H., Voss, W. D., Wright, B., Bender, W. I., Wurst, J. M., & Tippin, J. M. (1999). Depression in multiple sclerosis: Relationship to capacity-demanding memory and attentional functioning. *Neuropsychology*, *13*, 434–446.

Beck, A. T., & Steer, R. A. (1987). *BDI: Beck Depression Inventory Manual*. New York: Psychological Corporation.

Benedict, R. H. B., Fischer, J. S., Archibald, C. J., Arnett, P. A., Beatty, W. W., Bobholz, J., Chelune, G. J., Fisk, J. D., Langdon, D. A., Caruso, L., Foley, F., LaRocca, N. G., Vowels, L., Weinstein, A., DeLuca, J., Rao, S. M., & Munschauer, F. (2002). Minimal neuropsychological assessment of MS patients: A consensus approach. *The Clinical Neuropsychologist*, *16*, 381–397.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.

Conover, W. J. (1980). *Practical nonparametric statistics* (2nd ed.). New York: Wiley.

Delis, D. C., Kramer, J. H., Kaplan, E., & Ober, B. A. (1987). *The California Verbal Learning Test—Research Edition*. New York: Psychological Corporation.

DeLuca, J., Gaudino, E. A., Diamond, B. J., Christodoulou, C., & Engel, R. A. (1998). Acquisition and storage deficits in multiple sclerosis. *Journal of Clinical and Experimental Neuropsychology*, *20*, 376–390.

Demaree, H. A., DeLuca, J., Gaudino, E. A., & Diamond, B. J. (1999). Speed of information processing as a key deficit in multiple sclerosis: Implications for rehabilitation. *Journal of Neurology, Neurosurgery, and Psychiatry*, *67*, 661–663.

Donofrio, N., & DeLuca, J. (2001). The generation effect in multiple sclerosis: A means of improving new learning? [Abstract]. *Journal of the International Neuropsychological Society*, *7*, 251.

Higginson, C. I., Arnett, P. A., & Voss, W. D. (2000). The ecological validity of clinical tests of memory and attention in multiple sclerosis. *Archives of Clinical Neuropsychology*, *15*, 185–204.

Kurtzke, J. F. (1983). Rating neurologic impairment in multiple sclerosis: An Expanded Disability Status Scale (EDSS). *Neurology*, *33*, 1444–1452.

Lublin, F. D., & Reingold, S. C. (1996). Defining the clinical course of multiple sclerosis: Results of an international survey. *Neurology*, *46*, 907–911.

Nyenhuis, D. L., Rao, S. M., Zajecka, J. M., Luchetta, T., Bernardin, L., & Garron, D. C. (1995). Mood disturbance versus other symptoms of depression in multiple sclerosis. *Journal of the International Neuropsychological Society*, *1*, 291–296.

Poser, C. M., Paty, D. W., Scheinberg, L., McDonald, I. W., Davis, F. A., Ebers, G. C., Johnson, K. P., Sibley, W. A., Silberberg, D. H., & Tourtellotte, W. W. (1983). New diagnostic criteria for multiple sclerosis: Guidelines for research protocols. *Annals of Neurology*, *13*, 227–231.

The Psychological Corporation. (1997). *WAIS-III and WMS-III technical manual*. San Antonio, TX: Author.

Raaijmakers, J. G. W., & Shiffrin, R. M. (1981). Search of Associative Memory. *Psychological Review*, *88*, 93–134.

Rao, S. M., Leo, G. J., Bernardin, L., & Unverzagt, F. (1991). Cognitive dysfunction in multiple sclerosis. I. Frequency, patterns, and prediction. *Neurology*, *41*, 685–691.

Rao, S. M., Leo, G. J., Ellington, L., Nauertz, T., Bernardin, L., & Unverzagt, F. (1991). Cognitive dysfunction in multiple sclerosis. II. Impact on employment and social functioning. *Neurology*, *41*, 692–696.

Spreen, O., & Strauss, E. (1998). *Compendium for neuropsychological tests* (2nd ed.). New York, NY: Oxford University Press.

Walker, V. G. (1988). Durational characteristics of young adults during speaking and reading tasks. *Folia Phoniatrica*, *40*, 12–20.

Wechsler, D. M. (1955). *Manual for the Wechsler Adult Intelligence Scale*. New York: The Psychological Corporation.

Wechsler, D. M. (1987). *Wechsler Memory Scale—Revised*. San Antonio, TX: The Psychological Corporation.

Wechsler, D. M. (1997). *Wechsler Memory Scale–Third Edition*. San Antonio, TX: The Psychological Corporation.

Wilson, B. A., Cockburn, J., & Baddeley, A. (1985). *The Rivermead Behavioural Memory Test*. Reading, England: Thames Valley Test Co.

Wilson, B. A., Cockburn, J., Baddeley, A., & Hiorns, R. (1989). The development and validation of a test battery for detecting and monitoring everyday memory problems. *Journal of Clinical and Experimental Neuropsychology*, *11*, 855–870.

Wilson, B. A., Cockburn, J., & Baddeley, A., & Hiorns, R. (1991). *The Rivermead Behavioural Memory Test: Supplement Two*. Reading, England: Thames Valley Test Co.

Zachary, R. A. (1986). *Shipley Institute of Living Scale: Revised Manual*. Los Angeles: Western Psychological Services.