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A functional application of the spacing effect to improve learning and memory in persons with multiple sclerosis

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The present study examined the utility of using spaced learning trials (when trials are distributed over time) versus massed learning trials (consecutive learning trials) in the acquisition of everyday functional tasks. In a within-subjects design, 20 participants with multiple sclerosis (MS) and 18 healthy controls (HC) completed two route learning tasks and two paragraph reading tasks. One task in each area was presented in the "spaced" condition, in which the task was presented to the participants three times with 5-minutes break between each trial, and the second task in each area was presented in the "massed" condition, in which the task was presented three consecutive times to the participants. The dependent variables consisted of recall and recognition of the paragraphs and routes both immediately and 30 minutes following initial learning. Results showed that for paragraph learning, the spaced condition significantly enhanced memory performance for this task relative to the massed condition. However, this effect was not demonstrated in the route learning task. Thus, the spacing effect can be beneficial to enhance recall and performance of activities of daily living for individuals with MS; however, this effect was significant for verbal tasks stimuli, but not for visual tasks stimuli. It will be important during future investigations to better characterize the factors that maximize the spacing effect.

Keywords: Memory; Activities of daily living; Cognitive rehabilitation; Multiple sclerosis; Spacing effect.

INTRODUCTION

The influence of the timing of learning trials on acquiring and retaining newly learned information has a long history. At the turn of the 19th century, during his ground-breaking work characterizing the human memory system, Ebbinghaus (1885/1964) was the first to document that the spacing of learning trials influences retention. He noted that when he used consecutive repetitions to learn a 12-syllable series it took him 80 repetitions to learn the list without error. However, when the repetitions were spread over three days it took him only 38 practice sessions to achieve an errorless trial. Ebbinghaus termed this phenomenon the spacing effect (Cepeda, Pashler, Vul, Wixted, & Rohrer, 2006). These spaced learning trials differ from "massed" learning sessions, in which information is repeated in succession without interruptions. Thus, the spacing effect is the observation that information presented using spaced repetitions is better remembered than information presented via massed repetitions.

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The spacing effect appears to be a natural phenomenon of the human memory system that does not require conscious effort, training, or additional mental operations by the individual (Challis, 1993; Russo, Parkin, Taylor, & Wilks, 1998). Furthermore, Goetti (1996) suggests that information-processing style, task familiarity, and motivation are important factors when learning a task and may therefore influence the magnitude of the spacing effect. Research has demonstrated that the spacing effect is not modality specific. The spacing effect has been observed using verbal memory tasks, such as list recall, paired associates, and paragraph recall (Challis, 1993; Janiszewski, Noel, & Sawyer, 2003; Kahana & Greene, 1993; Krug, Davis, & Glover, 1990), facial recognition tasks (Mammarella, Russo, & Avons, 2002; Russo et al., 1998), picture learning (Hintzman & Rogers, 1973), skill learning, such as mirror tracing or video game acquisition (Donovan & Radosevich, 1999), and specific skill learning, such as aircraft recognition (Goetti, 1996). The spacing effect is noted for its ubiquity and robustness (Braun & Rubin, 1998; Challis, 1993).

To date, most of the research on the spacing effect has been conducted with healthy individuals in laboratory settings (e.g., Challis, 1993; Kahana & Howard, 2005; Janiszewski et al., 2003). Some researchers have examined how the spacing effect might facilitate learning and memory of different tasks in clinical populations who may exhibit memory deficits, including individuals with amnesia (Cermak, Verfaellie, Lanzoni, Mather, & Chase, 1996), dementia (Camp, Foss, Stevens, & O'Hanlon, 1996), and traumatic brain injury (Hillary et al., 2003). These studies indicate that the spacing effect can effectively facilitate retention of newly learned material in patients with memory impairments.

A significant number of individuals with multiple sclerosis (MS) suffer from impaired learning and memory (Bobholz et al., 2006; Drew, Tippett, Starkey, & Isler, 2008). Results from several recent MS studies suggest that the learning and memory deficits are due to impairment in initial acquisition of information rather than from impaired retrieval from long-term storage (DeLuca, Barbieri-Berger, & Johnson, 1994; DeLuca, Gaudino, Diamond, Christodoulou, & Engel, 1998; Gaudino, Chiaravalloti, DeLuca, & Diamond, 2001). Because new learning has been shown to be at the center of learning and memory disorders in MS, treatment must be focused on acquisition of new information, hence resulting in improved subsequent recall and recognition. While the spacing effect may prove to be especially beneficial, however, there are no studies examining the utility of the spacing effect in persons with MS.

Deficits in new learning and memory have important implications for everyday function such as activities related to work, school, and community integration (Beatty, Blanco, Wilbanks, Paul, & Hames, 1995; Finlayson, Impey, Nicolle, & Edwards, 1998). The application of memory strategies, such as the spacing effect, may positively affect everyday functional activity and overall quality of life (Barker-Collo, 2006; Shevil & Finlayson, 2006). To date, research examining the impact of the spacing effect is conducted primarily in the laboratory, and the influence of the spacing effect on everyday activities in clinical samples has not been studied.

If the spacing effect is indeed effective in improving learning and memory in MS, and its application can be extended to the learning of everyday activities, then the strategy can be integrated into rehabilitation protocols and aid in maximizing functional recovery. Therefore, the purpose of the present study was to determine whether spaced learning enhances memory of everyday functional tasks in persons with MS and to examine the differential influence of the nature of the learning task (visual procedural tasks vs. verbal episodic tasks).

METHOD

Participants

Participants consisted of 20 individuals with clinically definite MS, diagnosed according to the criteria of Poser et al. (1983), and 18 healthy control participants (HC). Participants were excluded from the present study if they had: (a) a history of neurological illness or injury (besides MS for the MS group); (b) a history of psychiatric illness; (c) a history of alcohol or drug abuse; or (d) severe visual or motor impairment. All individuals with MS were at least one month after the most recent exacerbation and were free of corticosteroid use. Demographic characteristics of the two groups are provided in Table 1. The two groups did not differ significantly with regard to age, education, or gender.

General procedures

Participants with MS were recruited by advertisements distributed at local support groups and clinics. HC were recruited via flyers and word of mouth throughout the local community. Upon

TABLE 1
Demographic data

	MS (n = 20)	*HC (n = 18)*	*F*	*p*
Age	48.4 ± 8.8	41.4 ± 12.9	3.8	*ns*
Education	15.3 ± 1.9	16.4 ± 1.5	3.7	*ns*
WRAT-3	49.5 ± 4.9	52.0 ± 3.0	3.5	*ns*
Gender (%)			$\chi^2(1) = 0.35$	*ns*
Males	20	33.3		
Females	80	66.7		
Disease type (%)				
Relapsing remitting	65	—		
Primary progressive	15	—		
Secondary progressive	20	—		
Disease duration (years)	10.6 ± 6.7	—		

Note. MS = multiple sclerosis. HC = healthy controls. WRAT-3 = Wide Range Achievement Test–Third Edition. *ns* = not significant.

initial phone contact, potential participants were screened for participation based on the inclusion/exclusion criteria discussed above. Participants were then scheduled for interview and testing. All recruitment and experimental procedures were approved by the Institutional Review Board (IRB) and Health Insurance Portability and Accountability Act (HIPAA) compliance boards. Before study enrollment, all participants indicated willingness to participate in the study by signing a consent form approved by the IRB. The testing session lasted approximately 2 hours, in which the neuropsychological battery and the spacing effect protocol were administered. All participants were paid for their participation.

Neuropsychological measures

All participants enrolled in the study went through neuropsychological testing to assess their current levels of cognitive performance. The neuropsychological measures utilized in this study are presented in Table 2.

Emotional measures

State–Trait Anxiety Inventory (STAI; Spielberger, 1983)

The STAI is a commonly used, standardized measure of anxiety. Higher STAI "state" and "trait" scores correspond to more anxiety. Both STAI "state" and "trait" scores were used in data analysis.

Chicago Multiscale Depression Inventory (CMDI; Nyenhuis et al., 1998)

This is a 50-item self-report measure designed to assess depression in MS and other chronic medical populations. The CMDI contains three subscales—Mood, Evaluative, and Vegetative (24 questions)—and 18 items that are not related to any of the three subscales. The total CMDI score was used in the present study as a measure of depressive symptomatology.

Memory tasks

The two memory tasks included in this study were a paragraph learning task and a route learning task. These tasks were developed for this study by the first and second authors of this study. The goal

TABLE 2
Neuropsychological tests

Domain of function	*Test*	*Dependent measure*
Working memory	Digit Span subtest (WAIS–R).	Sum of the number of correct responses for the Digit Span Forward and Backwards tests.
Processing speed	SDMT–oral version	Total number of correct responses in 90 s.
Learning and memory	CVLT	Total words recalled in Trials 1–5 and Discriminability score, as they are asserted to be most sensitive to cognitive impairment in persons with MS.
Executive functions	D-KEFS	
	Trail Making Test	Score from the Number–Letter Switching subtest.
	Verbal Fluency Test (Letter Fluency)	Sum of the number of words generated within 1 minute with each of the three letters (F, A, S).
	Color–Word Interference Test (Inhibition/Switching)	Time to completion on the Inhibition/Switching.

Note. WAIS–R = Wechsler Adult Intelligence Scale–Revised manual; Wechsler, 1981. SDMT = Symbol Digit Modalities Test (Smith, 1982). CVLT = California Verbal Learning Test (Delis, Kramer, Kaplan, & Ober, 1987). D-KEFS = Delis–Kaplan Executive Function System (Delis, Kaplan, & Kramer, 2000).

in using these separate tests was to measure verbal and nonverbal learning and memory processes on tasks that could be encountered during day-to-day functioning. The Paragraph Learning Task is verbal stimulus whereas the Route Learning Task is visual in nature. Each of these tasks was developed with alternate forms. These alternate forms were equivalent in the number of items to be remembered and recalled; the Paragraph Learning Task involved two different paragraphs, and the Route Learning Task included two black-and-white maps. For each task, participants received a total of three learning trials, and exposure to the task materials during the learning trials was either massed or spaced.

Paragraph Learning Task

The Paragraph Learning Task required the participant to read aloud two short paragraphs (one in a massed condition and one in a spaced condition, described below) three times. Both paragraphs were taken from a newspaper and contained 84 words, five sentences, and 14 elements of information. Following the three learning trials, two recall trials were conducted: (a) immediate recall, and (b) 30-minute delayed recall. Participants were asked to repeat back the paragraph provided to them "as close to the same words as possible." The dependent measures of this task were total number of elements recalled for each of the immediate and delayed free recall trials, ranging from 0 to 14.

Route Learning Task

The Route Learning Task was designed to simulate the procedure of learning and recalling a simple set of visual instructions when a new route is learned (e.g., when traveling to a new place). The routes were taken from a tour map of London. Each of the routes to be learned consisted of 13 different streets and 13 "turns" to be memorized. The three learning trials consisted of the examiner visually presenting the route (including the route streets and turns) using a red laser pointer on a map. During the presentation of the route, the examiner was positioned across a table from the participant, and each route presentation lasted 20 seconds. Following three learning trials, a recall trial was obtained by asking the participant to draw the route on the map without further presentation. An identical recall trial was performed after a 30-minute delay. For every correct turn and street traced, 1 point was awarded. The range of possible scores ranged from 0 (not remembering anything) to 26 (accurate recollection of the route). The dependent variables were the total score for immediate and delayed free recall trials.

Massed and spaced trials procedure

Figure 1 provides summary of the two testing procedures. In a within-group design, each participant was presented with two versions of each task. One version of each task was presented in a massed condition and one in a spaced condition. The condition (spaced vs. massed) and order of task presentation were counterbalanced to control for systematic order effects. For example, if one participant initially learned the Route Learning Task (Version a) in a spaced condition and Route Learning Task (Version b) in a massed condition, than the second participant started with the Paragraph Learning Task (Version a) in a spaced presentation and the Paragraph Learning Task (Version b) in a massed presentation. This participant proceeded with Route Learning Task (Version a) learned in a massed condition and Version b in a spaced condition and so on.

Procedures for the spaced condition: In the spaced condition, the participants were asked to read a single paragraph aloud or watch as a route was traced on a single map with a laser pointer by the researcher. Following a 5-minute delay, during which participants completed neuropsychological tests, participants were asked to again read the same paragraph aloud or watch the identical route map traced a second time. This procedure was repeated once again after yet another 5-minute delay (again, neuropsychological test were completed during this break). Immediately following this third presentation, participants were asked to recall the learned information (either the paragraph or the route). The immediate free recall of either the paragraph or route tasks was followed by a 30-minute delay during which the participants completed several additional neuropsychological tests (described in the neuropsychological testing) and then once again were asked to recall the learned material.

Procedures for the massed condition: In the massed condition, participants were present with three consecutive presentation of the to-be-learned material (either paragraph or route), followed by an immediate free recall trial. Following a 30-minute delay participants were again asked to recall as many details from the paragraph as possible and to reproduce the map route.

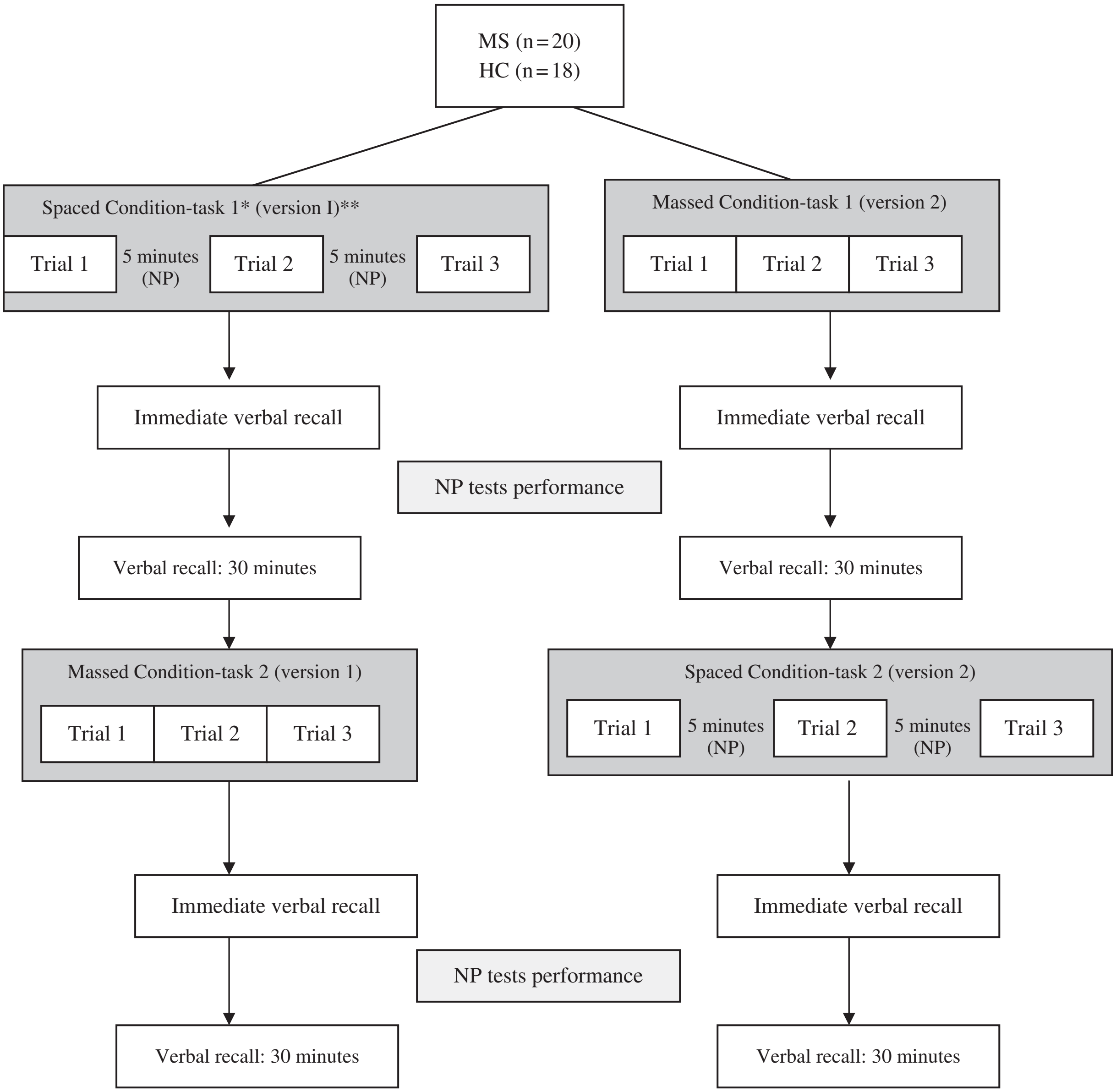

Figure 1. Study procedural flow of the spacing effect protocol for both MS and HC participants. *Task refers to either following a route on a map or paragraph learning. **Version refers to the two alternative versions related to each task (two versions to each: Version a and Version b). NP refers to neuropsychological testing.

Data analysis

To determine differences in demographic, neuropsychological, and behavioral characteristics between the two groups, one-way analyses of variance (ANOVAs) were conducted. To analyze performance on the spacing effect protocol, performance on the paragraph and route tasks were each analyzed by a 2 (group: MS vs. HC) × 2 (condition: massed vs. spaced) × 2 (time: immediate vs. 30 minutes) repeated measures ANOVA with group as the between-group factor and condition and time as within-group factors. Effect size was determined by calculating η^2.

RESULTS

Neuropsychological and emotional functioning

Cognitive and emotional functioning for the MS and HC participants are presented in Table 3. The MS group performed significantly worse than the HC group on all tasks except for the California Verbal Learning Test (CVLT; sum of five trials) and Digit Span Backward. With regard to emotional functioning, scores on the STAI did not differ significantly between groups and fell within the normal range when compared to published normative

TABLE 3
Neuropsychological test performance

Domain assessed	*Test*	*MS (n = 20)*	*HC (n = 18)*	*F*	η^2
Processing speed	SDMT	48.7 ± 11.5	58.6 ± 11.6	7.6**	.16
Episodic memory	CVLT–sum of 5 trials	52.1 ± 11.8	55.5 ± 10.0	0.87	.02
	CVLT–Discriminability	91.3 ± 7.9	96.2 ± 3.9	5.4*	.13
Working memory	Digit Span Forward	9.5 ± 2.3	11.3 ± 1.5	7.6**	.17
	Digit Span Backward	6.8 ± 2.2	8.0 ± 2.4	2.3	.06
Executive functions	D-KEFS Trail Making Test: Number–Letter Switching	104.2 ± 37.5	62.8 ±15.1	18.9**	.35
	D-KEFS Verbal Fluency–Letter Fluency	34.1 ± 11.6	43.1 ± 11.8	5.5*	.13
	D-KEFS Color–Word: Inhibition and Switching	75.1 ± 21.9	56.8 ± 14.8	8.7**	.20
Affect symptomatology	STAI–state anxiety	33.0 ± 8.3	31.1 ± 8.8	0.49	.01
	STAI–trait anxiety	40.3 ± 11.7	36.0 ± 7.0	0.18	.04
	CMDI	86.5 ± 32.4	66.1 ± 15.8	5.8*	.13

Note. MS = multiple sclerosis. HC = healthy controls. SDMT = Symbol Digit Modalities Test. CVLT = California Verbal Learning Test. D-KEFS = Delis–Kaplan Executive Function System. STAI = State–Trait Anxiety Inventory. CMDI = Chicago Multiscale Depression Inventory. Means ± standard deviations.
*$p < .05$; **$p < .01$.

data. However, MS participants reported significantly more depressive symptomatology than HC on the CMDI.

Performance of paragraph learning task

Condition: Spaced versus massed

Performance on the Paragraph Learning Task is presented in Figure 2. The mean number of elements recalled under the spaced condition was significantly higher (M = 7.87) than tasks that were presented in a massed condition (M = 7.25), collapsed across group and time, condition main effect (spaced versus massed), $F(1, 36) = 4.2$, $p < .05$, demonstrating a small effect size ($\eta^2 = .10$).

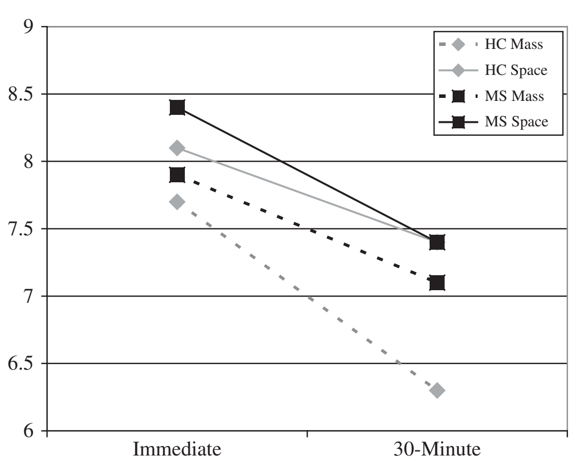

Figure 2. Paragraph Learning Task: Recall scores for spaced (solid lines) versus massed (dotted lines) conditions at each recall time for the multiple sclerosis (MS) and for the healthy control (HC) participants.

Group: MS versus HC

The MS and HC groups did not differ significantly in the mean number of tasks items recalled collapsed across time and condition; thus the main effect of group was not significant, $F(1, 36) = 0.16$, $p = .68$, $\eta^2 = .005$. Additionally, the relative difference between the spaced versus massed conditions was equivalent across participant groups, as indicated by the lack of a significant Group (HC vs. MS) × Condition (spaced vs. massed) interaction, $F(1, 36) = 0.55$, $p = .15$, with a small effect size ($\eta^2 = .01$). Thus, both HC and MS participants benefited equally from spaced learning, across time during paragraph recall.

Time

As expected, immediate recall was superior to delayed recall when considering the entire sample, $F(1, 36) = 32.7$, $p < .001$, $\eta^2 = .47$. However, no interaction was observed between time and condition, or between time and condition and group, suggesting that participants benefited similarly from learning new material in the spaced condition regardless of group membership or time of testing.

Following a route on a map

Spaced versus massed conditions

Performance of the route learning task is presented in Figure 3. There were no significant differences between the spaced and massed learning conditions for either the immediate or the 30-minute delayed recall of the Map Learning Task. Thus, there was no effect of distributed

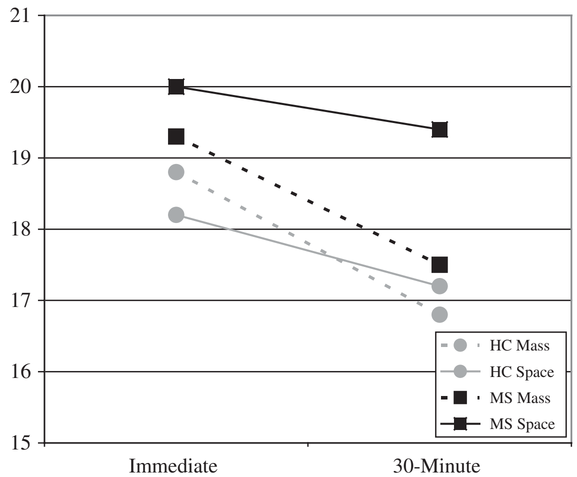

Figure 3. Following a route on a map: Recall scores for spaced (solid lines) versus massed (dotted lines) conditions at each recall time for the multiple sclerosis (MS) and for the healthy control (HC) participants.

learning on the route task (M = 18.15), condition main effect: $F(1, 36) = 0.45$, $p = .50$, $\eta^2 = .01$.

MS versus HC

The main effect of group was not significant, $F(1, 36) = 0.34$, $p = .56$, $\eta^2 = .009$, indicating that the MS and HC groups did not differ significantly in the mean number of items recalled. Similar to the paragraph tasks, the interaction of participant group and condition (i.e., spaced vs. generated) was not significant, $F(1, 36) = 0.41$, $p = .52$, $\eta^2 = .01$.

Time

As expected, the participants performed better during the immediate than during the delayed recall: time main effect, $F(1, 36) = 10.6$, $p < .01$, $\eta^2 = .22$. However, similar to the reading paragraph task, no interaction was observed between time and condition, or between time and condition and group.

DISCUSSION

Studies of cognitive rehabilitation and memory retraining have typically reported behavioral improvements on laboratory-based tasks, but these findings have proven difficult to extend to functional tasks of everyday activities (Wilson, 1992). One goal of the current study was to apply the spacing effect, a classic phenomenon in learning and memory literature, to tasks with greater face validity. The findings from the present study indicate that the spacing effect improves learning and memory of a paragraph reading task, but not a route learning task. These results suggest that the spacing effect can successfully be applied to a functional task (paragraph reading) in a neurologically impaired sample with MS; however, the efficacy of the spacing effect may be task specific. These results contribute to growing literature that spaced learning can produce significant functional improvements. For instance, the effectiveness of using spaced learning in applied settings (i.e., classroom) to improve paragraph reading has been previously demonstrated in studies of healthy individuals examining acquisition of novel material (Cepeda et al., 2006), memory for the main points of a text (Reder & Anderson, 1982), and learning new concepts in biology (Reynolds & Glaser, 1964). To our knowledge, the present study is the first study to use the spacing effect to enhance memory performance in persons with MS and to examine the impact of the spacing effect on learning of functional, everyday tasks in neurological samples.

The current study showed that the efficacy of the spacing effect was different across tasks such that spaced learning trials were beneficial for participants on the paragraph learning task, but not for the following a route on a map task. Three potential explanations for this differential effect stem from a meta-analysis conducted by Janiszewski et al. (2003), who included 97 articles examining the use of the spacing effect in an applied setting. In this meta-analysis review, these authors examined which variables either strengthened or weakened the spacing effect on memory performance. Janiszewski et al. concluded that the benefits of spaced learning were significantly greater in recall of memory-based choice of verbal stimuli than visual stimuli. Second, spacing effect was greater for semantically complex stimuli (e.g., homographs) (Challis, 1993; Greene, 1989) than for structurally complex stimuli (e.g., the sentence “The bird is on the green brick wall”) that are organizational (e.g., position in list) or contextual (e.g., learning episode, learning location, font, color). The Route Learning Task, in the present study, can be considered to be a memory-based task of structurally complex stimuli in which the learning cues are contextual. Therefore, it is not surprising that the spacing effect did not influence learning and memory for this particular functional task. A third factor that influences the strength of the spacing effect is the meaningfulness of the stimuli. That is, the effect of spaced learning has been shown to be greater for meaningful stimuli than for nonmeaningful stimuli (Janiszewski et al., 2003). It is possible that that the London route learning task was less meaningful for persons in this study and may account for the lack of the spacing effect's impact on learning and memory of this task whereas the paragraphs were about real-life stories taken from the newspaper.

From a theoretical perspective, one theory proposed to underline the efficacy of the spacing effect is the "diminished processing theories." The diminished processing theories predict a weaker spacing effect for isolated stimuli (versus embedded stimuli) because it is easier to retrieve an isolated stimulus at the second presentation. Thus, processing at the second presentation is more of an automated process. The stimuli for both the paragraph and route learning tasks used in the present study are embedded. Thus, according to the diminished processing theories, both the paragraph and route learning tasks in the present study should show a robust spacing effect. However, the fact that a spacing effect was only observed in the paragraph task is inconsistent with a broad interpretation of the diminished processing theories of spaced learning.

There are several potential limitations of the present study. First, the tasks used in this study were designed specifically for this experiment. Thus, there are questions related to reliability and validity that were not addressed by the design of this study. However, it is important to note that also in rehabilitation settings therapists use tasks that have face validity in treatment and not necessary ecological validity. Second, there was significant variability in the performance on the route learning task (e.g., $M = 19.4$, $SD = 6.4$, for spaced trial, and $M = 17.5$, $SD = 7.3$, for massed trial for the MS group), which diminished the likelihood of detecting what may have been a small but positive influence of the spacing effect on new learning. Third, the MS and HC groups differed on the amount of depressive symptomatology reported. One could hypothesize that depressive symptomatology had an effect on learning. However, because the current study employed a within-subjects design, each participant served as his/her own control; thus, depression is controlled in this type of design for the effect of distributed trials on learning. Third, the upper thresholds for the influence of the spacing effects on functional, more everyday tasks are not known. It is difficult to equate the challenges involved in performing the paragraph and route learning tasks, the least of which is because of their fundamental modality differences. One possible explanation for the differential effects between the paragraph and route learning tasks is task load. In other words, it is possible that the amount of information displayed in the route learning task was above some learning threshold for the spacing effect to be effective. Future spacing effect research on functional tasks could focus initially on applying very simple visuospatial tasks and incrementally increasing the difficulty. Despite these limitations, further study of the spacing effect on functional tasks is needed to determine the amount of information to be learned and/or the type of information, task(s), or skills that will most benefit from spaced learning method.

While there is still much left to learn about the optimal conditions for spaced learning to be effective, the present study has some important implications for cognitive rehabilitation in MS. The onset of MS typically occurs when individuals are most active and most productive in many aspects of their lives (Reingold, 1995). The impairments caused by MS usually lead to significant disruptions in persons' quality of life (QOL) and employment status (Neath, Roessler, McMahon, & Rumrill, 2007; Pompeii, Monn, & McCrory, 2005). Due to the significant relationship between cognitive/memory impairment, QOL, and employment status among individuals with MS, the treatment of deficits through strategies designed to improve new learning and memory could serve to significantly improve the QOL and community participation of individuals with MS. Therefore, the potential benefit of applying spaced learning during rehabilitation is significant, since it represents an important step towards designing unique treatment interventions that can be used to improve the learning of new functional tasks. Harnessed appropriately, the spacing effect could provide rehabilitation specialists with a potential tool that addresses deficits in new learning. While the efficacy of the spacing effect in enhancing memory performance is promising, its clinical utility in the rehabilitation of memory requires further research to examine variables such as the type of tasks learned, time between learning intervals, and what patient groups will gain the most benefit using this strategy.

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