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The effect of massed and spaced presentation and practice on repetition priming

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The Effect of Massed and Spaced Presentation and Practice on Repetition Priming

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Abstract

This review examines the current literature with regard to repetition priming and practice. The empirical research and theoretical accounts of repetition priming reviewed indicate that repetition priming increases with practice. The review also indicates that an effect for the type of presentation of the stimuli during an experiment exists and that this effect may moderate the influence of practice on repetition priming. The variations in experimental design between studies are discussed, providing a possible explanation for contrasting findings within repetition priming research. Further research is identified and discussed.

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A Review of the Effect of Practice on Repetition Priming

An individual may not consciously recollect having encountered a particular stimulus before, yet may behave in ways that clearly indicate prior experience with that event (Smith, MacLeod, Bain, & Hoppe, 1999). Information retrieved from memory without conscious control is referred to as implicit memory, whereas information retrieved with awareness is known as explicit memory (Graf & Schacter, 1985). In addition, research by Warrington and Weiskrantz (1974, 1978, 1982) has demonstrated that amnesics are able to become more proficient at completing various implicit memory tests, despite an inability to remember completing them. The findings of Smith et al. (1999) and Warrington and Weiskrantz (1974, 1978, 1982) have led to the argument that implicit memory tests, such as repetition priming are another form of skill acquisition that are governed by the power law. The power law states that performance on the implicit memory test will increase with practice on the task with performance improving dramatically at the beginning of practice and improvement gradually becoming increasingly less as the amount of practice increases. The effect of practice on repetition priming is examined in greater detail in this review. The theories proposed to explain the relationship between practice and task performance are presented and variations in experimental design are highlighted as a possible explanation for the sometimes conflicting empirical results found for the effect of practice on priming.

According to Graf and Schacter (1985) when participants are presented with word fragments of previously presented words and new words, and are then instructed to complete them with the first words that come to mind, subjects perform better with previously presented words than the new words. The aforementioned facilitation in performance found for implicit memory tests is known as repetition priming (Graf & Schacter, 1985). Repetition priming occurs when the prior response to a stimulus improves performance on a subsequent presentation of the same stimulus.

Repetition priming can be observed in a number of implicit memory tests including word-stem completion tasks (Jacoby, 1983), word fragment identification (Jacoby, 1983) and word identification tasks (Feustal, Shiffren, & Salasoo, 1983). However, one task predominantly used to study repetition priming has been the lexical decision task (Kirsner & Smith, 1974; Kirsner & Speelman, 1996). In a lexical decision task a letter string is presented and participants have to decide if the string is a word or nonword. Responses to repeated words have been found to be faster and more accurate than to words that have not been repeated (Kirsner & Smith, 1974).

Historically, repetition priming has been examined by presenting the target stimulus (e.g., the repeated word in a lexical decision task) only once in an initial study phase followed by a test phase, and the improvement in performance is specific to that particular stimulus (Cofer, 1967; Kirsner & Smith, 1974; Morton, 1969). Generally, researchers did not give consideration to the examination of the effect of multiple presentations of a repeated stimulus (i.e., practice) until Logan completed a series of studies in 1988 and 1990 using the lexical decision task. Logan (1990) found that repetition priming (i.e., the amount of facilitation repetition affords a word) increased with the number of practice trials (i.e., the number of presentations of the target word). In contrast, Kirsner and Speelman (1996) found that repetition priming occurred only after a single presentation of the repeated word (target stimulus). The conflicting reports on the effect of multiple presentations of target stimuli (words) found by Logan (1990) and Kirsner and Speelman (1996) are examined in greater detail later in this review.

The finding that performance on lexical decision tasks has been shown to improve with practice on the task (Logan, 1990) led to the investigation of repetition priming in the framework of skill acquisition. The phenomenon of skill acquisition has been intensively researched predominantly using motor tasks rather than cognitive performance (Pear, 1948;

Fitts, 1964). Skill acquisition, as opposed to repetition priming, is defined as the acquisition of procedures and operations that occurs as a function of practice (Schwartz & Hashtroudi, 1991). Fitts (1964) was the first to describe skill acquisition as involving cognitive processes, resulting in his proposal that skill acquisition involves three stages: the cognitive stage, the associative stage and finally the autonomous stage (see Fitts, 1964 for a review). This view was extended by Anderson (1982) with his ACT theory.

Although repetition priming and skill acquisition had both been studied individually at length three to four decades ago, the potential relationship between the two implicit phenomena was not recognized or investigated until the work of Logan (1990), Schwartz and Hashtroudi (1991) and Kirsner and Speelman (1996). Logan (1990) was the first to propose the argument that repetition priming was a form of skill acquisition following his studies using multiple presentations of the target stimulus. As previously stated, Logan (1990) found that repetition priming (i.e., the amount of facilitation repetition affords a word) increased with the number of practice trials.

In contrast, Schwartz and Hashtroudi's (1991) studies did not support Logan's view. They dissociated priming and skill learning in a series of studies. Schwartz and Hashtroudi observed increases in skill learning in partial word identification tasks but the amount of priming did not differ with practice. Schwartz and Hashtroudi concluded that repetition priming and skill learning involved two different types of memory processes: priming involves specific occurrences and skill learning involves operations and procedures. Schwartz and Hashtroudi summarized the distinction between skill learning and repetition priming using clinical studies that found skill learning has been impaired by subcortical dementia (e.g., Huntington's disease) whereas repetition priming was impaired by cortical dementia (e.g., Alzheimer's disease).

Kirsner and Speelman (1996) found the results of Logan (1990) and Schwartz and Hashtroudi (1991) difficult to reconcile. Kirsner and Speelman (1996) supported the view that repetition priming was a form of skill acquisition whereby repetition priming would increase with increasing number of presentations of the target stimulus (i.e., practice). However, as previously reported, in their own experiment they found that repetition priming occurred only after a single presentation of a repeated word (target stimulus) and that priming did not increase with further presentations.

Theoretical Accounts of the Relationship between Skill Acquisition and Repetition Priming

The supposition that repetition priming is a form of skill acquisition has been supported by the theories of Anderson (1982), Logan (1988; 1990) and Kirsner and Speelman (1996). All these recent theories agree that practice can lead to skilled performance (Speelman & Kirsner, 1997). However, these theories are in contrast to earlier theories such as the Logogen Model proposed by Morton (1969) which does not predict that repetition priming will increase with practice.

Morton's Logogen Model (1969) has the logogen as the basic unit of word recognition. The logogen is proposed as a device that accepts information relevant to a particular word response. Each logogen has a resting level of activation and a threshold. The response to a word becomes available when the amount of information regarding a particular word response rises above the threshold level. Morton found that the stimulus information was only effective for a short period of time after presentation and that the logogen quickly returned to its resting level of activation. Therefore, no interaction between successive presentations of the stimulus word was expected unless the stimulus words were presented in quick succession. It should be noted however that Morton only used two presentations of his stimuli and thus, using Morton's Logogen Model, it is difficult to predict that repetition priming will increase with increased repetitions of the stimulus unless the stimulus words are presented in very quick succession.

On the contrary, Logan's (1990) Instance theory of skill acquisition states that repetition priming increases cumulatively with the number of times a word is presented in lexical decision. Logan (1990) used multiple presentations of his target stimuli during his studies. Logan's Instance theory proposes that improvement in performance is a result of an increased range of separate episodic memory representations of past experience (repeated words) stored for later retrieval. According to Logan, each individual exposure to the target (repeated) word is stored and retrieved in memory as an individual 'instance' that is a separate episodic memory representation. With task practice (lexical decision) the number of instances increases and the retrieval process becomes automatic as past solutions are retrieved. The more instances stored in memory to retrieve, the faster the reaction time to the repeated word.

Logan (1990) found that repetition priming conformed to the power law of learning. In simplistic terms, performance improves dramatically at the beginning of practice but as the task proceeds and the amount of practice increases, improvement in performance becomes increasingly less, as represented in Figure1.

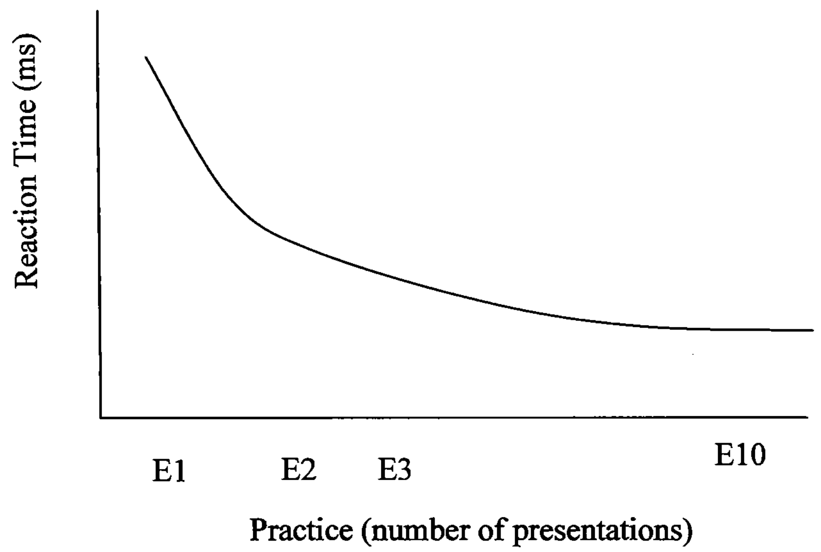

Figure 1. The effect of practice on reaction time in a lexical decision task reflecting the power law of learning – Logan (1990).

Logan (1988; 1990) measured repetition priming as the difference between the reaction time of the successive presentation of the repeated target word (old word) and the reaction time to the initial presentation of the target word. For example, in Figure 1 successive priming values would be measured as (E2 old word reaction time) – (E1 old word reaction time); (E3 old word reaction time) – (E1 old word reaction time); etc. Logan's measurement of priming predicts that the amount of priming will increase with increased presentations of a target (old) word. However, Logan's measurement of priming (1988; 1990) does not distinguish between task practice effects (lexical decision) and item effects (word repetition) and consequently does not account for the facilitation associated with getting better at the task.

In contrast, Kirsner and Speelman's (1996) Component Theory of Skill Acquisition takes task practice into account. Kirsner and Speelman proposed that although repetition priming and skill acquisition follow the same principle of learning, they are independent processes that benefit from different amounts of practice. In other words, the Component Theory of Skill Acquisition proposes that performance on lexical decision tasks reflects improvement on component tasks that have been practiced to different extents. In a lexical decision task, the initial processing of words is a well practiced component for most adults but the lexical decision (i.e., the decision concerning whether a letter string is a word or nonword) is usually close to nil. Therefore, the performance on repetition priming is a function of shared components rather than specific instances experienced. Kirsner and Speelman found that once task practice is considered, repetition priming has a much smaller effect on overall performance. Task practice was controlled by calculating priming as the difference in the reaction time of the repeated target words (old) and the new words presented within each experimental block, as represented in Figure 2. For example, successive priming values are calculated as (E2 new word reaction time) – (E2 old word reaction time) and (E3 new word reaction time) – (E3 old word reaction time).

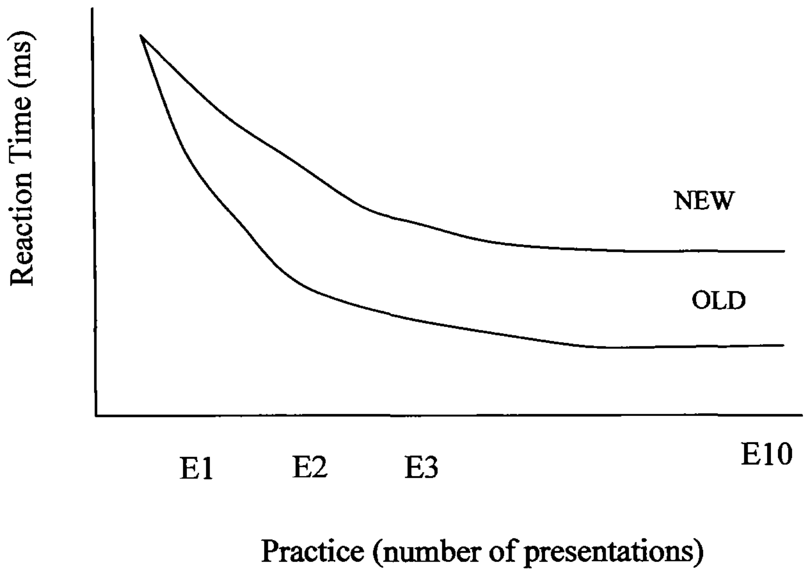

Figure 2. The effect of practice on reaction time in a lexical decision task – Kirsner and Speelman (1996).

Figure 2 demonstrates that it is more difficult to predict the effects of practice on repetition priming when task practice is controlled.

Kirsner and Speelman's (1996) study manipulated the frequency value of words (pre-experimental practice) and the amount of experimental practice (i.e., how often the words were encountered within the experiment). It was revealed that repetition priming occurred only after a single presentation of a repeated (old) word and that priming did not increase with further presentations. This result was contrary to the empirical findings of Logan (1988; 1992) and Kirsner and Speelman suggested that task practice effects may have contributed to Logan's priming results. Kirsner and Speelman's results also supported the frequency attenuation effect whereby priming of low frequency words was greater than for medium or high frequency words. Kirsner and Speelman suggested that this finding was the result of "extra laboratory practice". In other words, low frequency words have been practiced less by most adults and are therefore more sensitive to priming effects.

Whilst Logan's (1990) and Kirsner and Speelman's (1996) research experiments differed on their methods of the measurement of repetition priming, they both used lexical decision as the task type. However, they also differed on the type of presentation of their lexical decision task. Logan presented his experimental blocks of trials without any intervening items between these blocks (massed presentation i.e., 16 repetitions in 3 minutes). In contrast, Kirsner and Speelman had intervening items between the presentations of the blocks of trials (spaced presentation i.e., 7 experimental sessions presented on 7 successive days). This methodological difference in experimental design may have accounted for the differing empirical findings of Logan and Kirsner and Speelman.

Research into skill acquisition has traditionally focused on the best means of practicing a task and the relative benefits. That is, which type of practice is the most efficient training method: massed presentation – a stimulus is repeated on successive trials without any other items intervening between the repetitions, or spaced presentation – one or several items intervene between the repeated presentations of a stimulus (Ostergaard, 1998). It is possible that Logan's and Kirsner and Speelman's differing empirical findings may be explained or influenced by the effects of the type of presentation on their lexical decision tasks.

The Effect of Massed and Spaced Repetitions on Skill Acquisition and Repetition Priming

The majority of research into the massed presentation-spaced presentation effect has involved motor tasks and little research has been conducted using implicit perceptual tasks (Challis & Sidhu, 1993). It has been thought that spaced presentation was the most efficient training method (McGeoch, 1931). In contrast, a review of the literature by Adams (1987) rejected this finding. Adams found that spaced practice did not improve learning relative to massed practice. However, Adams did find that spaced practice improved the momentary level of performance but not the overall level of learning.

Adam's (1987) findings were not supported by a subsequent meta-analysis carried out by Lee and Genovese (1988). The meta-analysis of 47 studies determined that spaced presentation was superior to massed presentation when completing a simple motor task. Lee and Genovese refined their conclusions after completing further research in 1989. The later study used a movement timing task that involved two versions: a discrete version where the task was of short duration and had predefined start and stop points and a continuous version of longer duration and unknown start and stop times. The results showed a superior effect for massed presentation on the discrete task but a superior effect for spaced presentation on the continuous task. These findings have been further complicated by a subsequent meta-analytical review by Donovan and Radosevich (1999). Sixty-three studies with a mean weighted effect size of 0.46 revealed that the relationship between the type of presentation (massed or spaced) and performance is moderated by the nature of the task, the length of time between the spaced practice presentations and the interaction between the two variables.

Limited research has been conducted on the effect of type of presentation using implicit memory tasks (Cepeda, Pashler, Vul, Wixted & Rohrer, 2006; Russo, Mammarella & Avons, 2002). However, five studies did investigate the effect of massed presentation and spaced presentation on implicit memory tests. In general, it was found that massed presentation does not significantly increase the magnitude of priming over that with a single presentation of a primed stimulus (Challis & Sidhu, 1993; Greene, 1990; Jacoby & Dallas, 1981; Perruchet, 1989). Interestingly, when the presentations are spaced the conclusions are more confusing and contradictory. One set of studies was reported by Jacoby and Dallas (1981). They manipulated the spacing in two experiments using priming in the accuracy of perceptual identification as the implicit task. In both experiments, there was a small advantage for spaced items over massed items, although the effect was only significant for one of the experiments. Feustal, Shiffren and Salasoo (1983) reported a superior effect of spaced repetitions over massed repetitions in a word-identification task using a perceptual-clarification task, whereas Perruchet (1989) using the same implicit memory task, found a significant advantage for spaced presentations over massed in only one of four experiments. However, all these results could be due to a lack of power as the number of participants ranged from 32 to 48 respectively.

To ensure sufficient power Greene (1990) completed a series of experiments investigating the spacing effect using three implicit memory tasks: spelling homophonic words, word-fragment completion and perceptual identification with a sample size ranging from 60 to 120 participants per experiment. Greene found an increase in priming for information presented at separate points in time (spaced presentation) for spelling homophonic words and word-fragment completion but not for information presented consecutively (massed presentation). However, an increase in priming was only found under intentional learning conditions for the perceptual identification task and not under incidental learning conditions involving the implicit memory.

Challis and Sidhu's (1993) findings supported the contradictory evidence presented so far on the effects of massed presentations and spaced presentations on implicit memory tasks. They found massed presentation did not increase priming on word fragment completion beyond that obtained from a single presentation (n=90).

In summary, it appears that repetition priming may be sensitive to changes in experimental design, such as the type of presentation of the stimulus (massed or spaced). Also, it is evident that the type of implicit memory task used during research varies from lexical decision (Kirsner & Speelman, 1996; Kirsner & Smith, 1974) to word-fragment completion (Warrington & Weiskrantz, 1974) and word identification (Schwartz & Hashtroudi, 1991). Whilst repetition priming has been demonstrated across various implicit memory tasks, it is also possible that other experimental factors are responsible for the difference in the magnitude of priming found during Logan's (1990) and Kirsner and Speelman's (1996) research. In the following section, a number of factors are considered that have been identified as affecting the magnitude of repetition priming. The degree to which these factors may impact on the influence of practice on repetition priming is also discussed.

Experimental Design Factors Affecting Repetition Priming and Practice

Word Frequency

The frequency with which words appear in normal usage (e.g., text, conversation) has been shown to affect the amount of priming that is observed. Word frequency is often expressed as how often a word is encountered per one million words of text (Kucera & Francis, 1967). Research has generally shown that high frequency words (81 per million to 130 per million) are typically responded to faster and more accurately during a lexical decision task than low frequency words (1 per million) (Jacoby & Hayman, 1987; Kirsner & Speelman, 1996; McKone, 1995). Likewise with regard to accuracy, Jacoby and Hayman (1987) found that high frequency words were identified correctly 83.40% of the time whereas low frequency words were only identified 71.25% of the time under the same conditions.

However, it has been found that the magnitude of priming is greater for low frequency words than for high or medium frequency words (Bowers, 2000; Kirsner & Speelman, 1996). This result is known as the frequency attenuation effect. As previously stated, Kirsner and Speelman suggested that this finding was the result of "extra laboratory practice". In other words, low frequency words have been practiced less by most adults (pre-experimental practice) and are therefore more sensitive to priming effects.

Both Logan (1990) and Kirsner and Speelman (1996) used a range of word frequencies during their research. Logan used 340 common nouns of varying word frequency whereas Kirsner and Speelman used 576 words of varying word frequency. Logan (1990) reported an increase in repetition priming with practice for all word frequencies whereas

Kirsner and Speelman (1996) demonstrated that repetition priming is a one-shot effect for all word frequencies and is indifferent to practice. Logan's model does not take account of pre-experimental practice (i.e., how often the words of different frequencies are encountered prior to the experiment). Conversely, Kirsner and Speelman's model does take account of pre-experimental practice thus leaving only the effects of item practice (i.e., how often the words of varying frequencies are encountered during the experiment) on priming to be examined. Kirsner and Speelman's findings therefore account for item practice within the experiment only and consequently any effects of pre-experimental practice word frequency may be removed. However, as Logan's model takes no account of pre-experimental practice, it is possible that exposure to the words of varying word frequency prior to the task may have affected the influence of practice on repetition priming thus accounting for the increase in repetition priming with increasing practice for all word frequencies.

Type of Task

Several types of task have been predominantly used to measure the amount or magnitude of repetition priming (Schacter, 1987). The most commonly used tasks are lexical decision, word identification and word-stem or fragment completion. Word identification tasks (Jacoby & Dallas, 1981), also known as tachistosopic or perceptual identification, involve participants being given a very brief exposure (e.g., 30 ms) to a stimulus and then being required to identify it. Priming is indicated by an increase in the accuracy of identifying the recently exposed items relative to new items or by a decrease in the amount of exposure time necessary to identify the recently exposed items. On word completion tests (Jacoby, 1983), subjects are either given a word stem (e.g., cha_ _ for chair) or fragment (e.g., co_pu_ _ _ for computer) and are instructed to complete the word with the first word that comes to mind. Priming is reflected by an enhanced ability to complete the test stems or fragments with words previously studied on a list.

The studies reviewed so far have involved the use of the three predominant implicit memory tasks as measures of repetition priming and differing magnitudes of initial priming have been found thereby making generalization across studies limited. The type of task has usually been chosen by the researcher and then other variables, such as number of repetitions of the target word (Grant & Logan 1993), word frequency (Jacoby & Hayman, 1987) and modality of the stimuli (Kirsner & Smith, 1974) have been manipulated. Limited research has been completed that has examined the effect of task type.

According to Bowers (2000), different tasks are differentially affected by word frequency manipulations. During his investigative research into modality-specific and modality nonspecific components of long-term priming and word frequency, Bowers compared the amount of repetition priming between two task types. Two groups of 48 university students were tested using a lexical decision task and two further groups of 48 students were tested using a perceptual identification task that involved the determination of exposure time a word had to be displayed in order for each participant to identify the words 50% of the time. The frequency of the words was manipulated and it was found that the lexical decision task was more sensitive to word frequency (i.e., prior exposure to the words before the experiment) than the perceptual identification task. Thus, the result demonstrates the danger and difficulties of comparing studies that utilise different task types as their measures of repetition priming.

However, both Logan (1990) and Kirsner and Speelman (1996) used lexical decision as their type of task used to measure repetition priming. As it has been proposed that lexical decision is more sensitive to word frequency, it is possible that the frequency of the words presented during Logan's and Kirsner and Speelman's studies may explain the conflicting findings on the effect of practice on repetition priming as discussed in the previous section.

Surface Features

A number of experiments have demonstrated that priming is sensitive to the surface features of the stimuli (Bowers, 2000; Jacoby & Dallas, 1981; Jacoby & Hayman, 1987; Kirsner & Smith, 1974). Surface features include the modality of the stimuli (i.e., visual or auditory), the font size of the stimuli, the case of the stimuli and the texture of the stimuli.

Kirsner and Smith (1974) presented a lexical decision task to 24 students and varied the modality of the stimulus presentation. Massed presentation of the target stimuli was used and the frequency of the words was unknown. Four levels of the independent variable were manipulated: 1. the first presentation of the word/nonword stimuli was visual and the second presentation was verbal; 2. the first presentation was visual and the second was visual; 3. the first presentation was verbal and the second was visual and 4.the first presentation was verbal and the second presentation was verbal. It was found that the repetition priming effect was greatest for the intramodality conditions but that it still existed for the cross-modality conditions.

Jacoby and Hayman (1987) manipulated the case of the word/nonword stimuli presented to participants. The words were presented on a computer screen for either 30 *ms* or 35 *ms* and the participants' task was to identify the words. The study found that when the case in which the word was presented varied between the first and second presentations (e.g., UPPERCASE then lowercase) the chance of the participant identifying the word was less than when the first and second presentation of the word were presented in the same case (e.g., UPPERCASE then UPPERCASE). However, it should be noted that half the words studied were high frequency words and half were low frequency words and that the type of presentation (i.e., spaced or massed) of the target words was not known.

Logan (1990) and Kirsner and Speelman (1996) both presented their words visually in uppercase and in the centre of the computer screen. It is unlikely that surface features of the stimuli presented within each experiment had any influence on the effect of practice on the magnitude of repetition priming detected.

Presentation Context

Jacoby has carried out extensive research into the dissociation between explicit and implicit memory (Jacoby, 1983; Jacoby & Dallas, 1981). As part of his research, Jacoby has manipulated the context in which stimuli were presented. Jacoby presented students with a list of words during the study phase of an experiment and then compared performance on explicit memory tests and implicit memory tests. In his 1983 experiment, Jacoby manipulated the context in which the list of words was studied prior to testing. The manipulation involved whether or not participants read aloud a single word (e.g., COLD) out of context (xxx-COLD), read it in a meaningful context (hot-COLD), or generated it from the context (hot-????). Following the study, the participants took an explicit memory test (recognition) and an implicit memory test involving perceptual identification where the participants were shown a long list of words, some of which had been previously studied in the study phase and some which had not, at very fast rates (30ms). The participant was asked to read each word out loud. The greatest priming was found for words read out of context and the least for words that were generated. Jacoby argued that the no-context condition relied on perceptual encoding hence the greater priming.

Jacoby's (1983) finding was supported by Levy and Kirsner (1989, Experiment 1). Levy and Kirsner had manipulated the context of the target words presented to participants in the study phase of their experiment. Participants either processed a set of single words (isolation) or the same words within a passage. Perceptual identification was also used as the implicit memory measure. Levy and Kirsner found that priming was greatest for words presented in isolation.

Both Logan (1990) and Kirsner and Speelman (1996) presented their stimuli as single words. It is therefore unlikely that the presentation context of the stimuli would have had any impact on the conflicting findings of Logan and Kirsner and Speelman with regard to the effect of practice on repetition priming. Based on the findings of Jacoby (1983) and Levy and Kirsner (1989), the presentation of the stimuli as single words should have ensured that any priming taking place during both experiments would be more easily detected than if the words were presented in a different context.

Number of Presentations of the Old Words

The number of repetitions of a target word (old word) during a lexical decision task has been observed to influence the amount of priming. However, there are conflicting accounts of the effect of multiple presentations of old words during the task. Logan (1988; 1990) proposed that learning was a direct function of the number of times an old word was presented and that repetition priming therefore increases cumulatively with the number of times an old word is presented in lexical decision. Grant and Logan (1993) refined the finding during an exploration of the loss of priming as a function of the number of repetitions with lexical decision as the task type. The words used varied in frequency with a mean 75.27 per million (Kucera & Francis, 1967). Target words were presented up to 16 times (0, 1, 2, 4, 8 and 16) during Experiment 1, with priming increasing in a continuous, negatively, accelerated fashion. To be precise, priming increased dramatically with the initial repetitions of the target word, but the size of the increase was reduced with increasing repetitions.

In contrast, Kirsner and Speelman (1996) found that repetition priming occurred only after the single presentation of a word and did not increase with further repetitions when the item practice effects were isolated. The frequency of the words (equal high, medium and low frequency) was manipulated along with the number of repetitions of the target words (1 to 7 repetitions) and the implicit memory task was lexical decision.

Lag

Lag is the period of time between the first presentation of a stimulus and the second presentation of the stimulus (McKone, 1995). According to McKone, the size of the lag can affect the amount of priming detected during an experiment. In several studies using lexical decision, stimuli have been repeated at various lags by varying the number of trials intervening between target repetitions. This method ensures that the time delay between presentations is also varied (Kersteen-Tucker, 1991; Kirsner & Smith, 1974; Scarborough, Cortese & Scarborough, 1977). Kersteen-Tucker (1991), Kirsner and Smith (1974) and Scarborough, et al. (1977) all supported the view that priming is larger at Lag 0 (immediate repeat of target word and no intervening words presented between the target words) than at any later lag.

Both Logan (1990) and Kirsner and Speelman (1996) used multiple repetitions of their stimuli during their research. Logan (1990) presented the repetition of his words across massed trials (i.e., 16 repetitions in 3 minutes) whereas Kirsner and Speelman (1996) presented their stimuli over a period of 7 days. Thus the delay of time between the presentations of the target stimuli (lag) and the number of intervening items between the target stimuli could have contributed to the equivocal evidence found concerning the effect of practice on repetition priming.

Conclusion

This review of the current literature on the effect of practice on repetition priming has identified several current gaps in the research with regard to the effect of practice on repetition priming. At the time of this review, there are many factors that vary greatly between each study and hence comparison between studies is limited. The type of task used, the word frequency of the stimuli within the task, the number of repetitions of target stimuli and the type of presentation (massed – spaced) of the stimuli all differ from study to study. It is often hard to identify the cause of a finding because of the seemingly small and subtle variations in experimental design. To date, no clear outcome has been identified on the effect of the practice on repetition priming.

To allow generalisability between studies, it is suggested that the experimental design of research into implicit memory processes be standardised. Consideration should be given to the choice of task type used to measure repetition priming and it is suggested that only low frequency words (Kucera & Francis, 1967) are used. According to the frequency attenuation effect, a greater amount of priming should be more easily detected with low frequency words. The number of repetitions of a target word should also be standardized so that any priming effects can be clearly detected.

Additionally, task practice should be addressed for each study due to the conflicting evidence of Logan (1988; 1990) and Kirsner and Speelman (1996). It is suggested that Kirsner and Speelman's (1996) method of calculating priming (i.e., comparison of the reaction time of the repeated target words (old) and the new words presented within each experimental block) be adopted so that the priming associated with the item practice only is isolated.

In reference to the effect of massed presentation and spaced presentation on repetition priming, the current review has found support to suggest that an effect for massed versus spaced presentation exists. However, it is difficult to establish the effect due to the apparent sensitivity of repetition priming to small variations in experimental design thereby clouding the results of any intentionally manipulated variables. Hence, the effect of massed and spaced presentations on repetition priming warrants further investigation.

In conclusion, the current review has highlighted some evidence to indicate that the amount of repetition priming does increase with item practice. However, the evidence is equivocal. The magnitude of the priming is possibly dependent on the effects of, and possible interaction between, word frequency, the type of task, the type of presentation of the task, the number of presentations of the target stimuli, the surface features as well as the presentation context of the stimuli. The empirical findings of Logan (1988; 1990) and Kirsner and Speelman (1996) are conflicting on the notion that repetition priming increases with practice but support the proposal that the methodological design of the studies may have moderated the influence of the effect of practice on repetition priming.

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Zuckerman, M., DePaulo, B. M., & Rosenthal, R. (1986). Humans as deceivers and lie detectors. In P.D. Blanck, R. Buck, & R. Rosenthal (Eds.), *Nonverbal communication in the clinical context* (pp. 13–35). University Park: Pennsylvania State University Press.

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Research Report

The Effect of Massed and Spaced Presentation and Practice on Repetition Priming

Catherine McNeilly

Abstract

The aim of this study was to investigate the effect of Massed and Spaced presentation and practice on repetition priming. To facilitate this, a lexical decision task was used. Sixty participants comprising 30 university students and 30 members of the general public were asked to decide whether a letter string was a word or nonword. The participants were randomly assigned to one of three conditions: Massed presentation, Spaced presentation and Superspaced presentation. A total of 630 trials were presented to each participant comprising 300 new words, 270 nonwords and 20 old words which were repeated 3 times during the testing phase. The results indicated that the amount of priming increased with practice thus supporting the hypothesis that the amount of repetition priming would increase with increasing repetitions. It was also found that the Massed-Spaced effect may not be an issue. This finding was not congruent with the hypothesis that as spacing increases, the amount of increase in repetition priming would be reduced. Future research was recommended to clarify any advantage of the type of presentation on an implicit memory task.

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Submitted: October, 2007

The Effect of Massed and Spaced Presentation and Practice on Repetition Priming

Introduction

Over the last three decades, increasing attention has been paid to experimental research on implicit memory (Zeelenberg, Wagenmakers, & Shriffen, 2004). One of the main reasons for the interest in implicit memory has been a set of remarkable findings that have been reported with amnesics. Amnesia usually renders a person incapable of retaining new experiences but leaves other cognitive functions relatively intact. Research by Warrington and Weiskrantz (1974, 1978, 1982) has demonstrated that amnesics are able to become more proficient at completing various indirect memory tests, despite an inability to remember completing them. Smith, MacLeod, Bain and Hoppe (1999) also found that normal individuals may not consciously recollect having encountered a particular stimulus before, yet may behave in ways that clearly indicate prior experience with an event.

One possible implication of these findings is that there are two memory systems in operation. The implicit memory system allows information to be retrieved from memory without conscious control; whereas information retrieved with awareness is controlled by the explicit memory system (Graf & Schacter, 1985).

The predominant tool used to examine implicit memory has been repetition priming. Repetition priming occurs when a prior response to a stimulus improves performance on a subsequent presentation of the same stimulus (Graf & Schacter, 1985). One task predominantly used to study repetition priming has been the lexical decision task. In this task a letter string is presented and participants have to decide if the string is a word or nonword. Responses to repeated words have been found to be faster and more accurate than to words that have not been repeated (Kirsner & Smith, 1974). Furthermore, performance on the lexical decision task has been shown to improve with practice on the task (Kirsner &

Speelman, 1996). This finding has led to the investigation of repetition priming in the framework of skill acquisition. Skill acquisition has been defined as the acquisition of procedures and operations that occurs as a function of practice (Schwartz & Hashstroudi, 1991).

The supposition that repetition priming is a form of skill acquisition was first proposed by Logan (1988; 1990) and has been supported by the theories of Anderson (1982) 1990) and Kirsner and Speelman (1996). All these recent theories agree that practice can lead to skilled performance (Speelman & Kirsner, 1997). However, conflicting reports on the effect of multiple presentations (i.e., practice) of target stimuli (words) were found by Logan (1990) and Kirsner and Speelman (1996). Logan (1990) found that repetition priming (i.e., the amount of facilitation repetition affords a word) increased with the number of practice trials (i.e., the number of presentations of the target word). In contrast, Kirsner and Speelman (1996) found that repetition priming did not increase in magnitude beyond that afforded by a single presentation of the repeated word (target stimulus).

The Effect of Practice on Repetition Priming

Logan (1990) used multiple presentations of his target stimuli during his studies, and found that repetition priming increases cumulatively with the number of times a word is presented in lexical decision. To explain this observation, Logan's Instance theory proposes that improvement in performance is a result of an increased range of separate episodic memory representations of past experience (repeated words) stored for later retrieval. According to Logan, each individual exposure to the target (repeated) word is stored and retrieved in memory as an individual 'instance' that is a separate episodic memory representation. With task practice (lexical decision) the number of instances increases and the retrieval process becomes automatic as past solutions are retrieved. The more instances stored in memory to retrieve, the faster the reaction time to the repeated word.

Logan (1990) found that repetition priming conformed to the power law of learning. In simplistic terms, performance improves dramatically at the beginning of practice but as the task proceeds and the amount of practice increases, the amount of improvement in performance becomes increasingly less (see Figure 1).

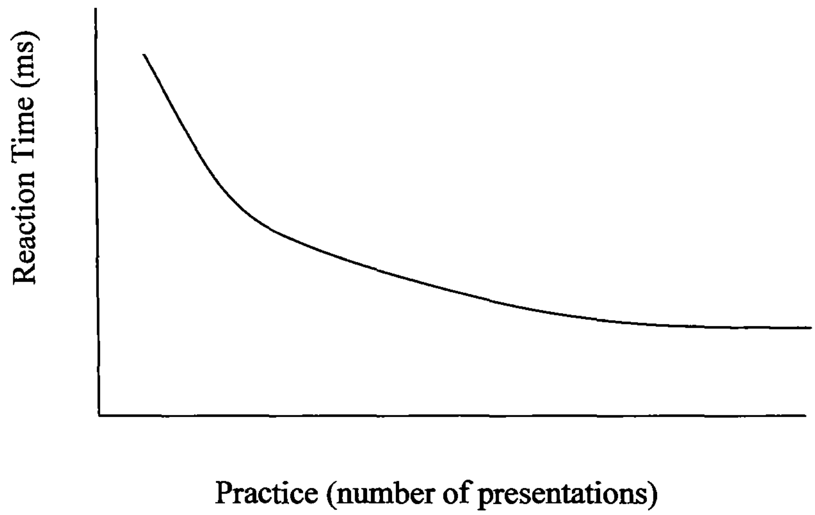

Figure 1. The effect of practice on reaction time in a lexical decision task reflecting the power law of learning

Logan (1988; 1990) measured repetition priming as the difference between the reaction time of the successive presentation of the repeated target word (old word) and the reaction time to the initial presentation of the target word. Logan's measurement of priming resulted in the amount of priming increasing with increased presentations of a target (old) word. However, Logan's measurement of priming did not distinguish between task practice effects (lexical decision) and item effects (word repetition) and consequently did not account for the facilitation associated with getting better at the task.

In contrast, Kirsner and Speelman's (1996) Component Theory of Skill Acquisition takes task practice into account. The Component theory also predicts that repetition priming will increase with increased repetitions. However, Kirsner and Speelman proposed that although repetition priming and skill acquisition follow the same learning principle, they are independent processes that benefit from different amounts of practice. In other words, the Component Theory of Skill Acquisition proposes that performance on lexical decision tasks reflects improvement on component tasks that have been practiced to different extents. In a lexical decision task, the initial processing of words is a well practiced component for most adults but the lexical decision (i.e., the decision concerning whether a letter string is a word or nonword) is usually close to nil. Therefore, repetition priming is a function of shared components rather than specific instances experienced. Kirsner and Speelman found that once task practice was considered, repetition priming had a much smaller effect on overall performance. Task practice was controlled by calculating priming as the difference in the reaction time of the repeated target words (old) in each block of trials and the new words presented within the same block of trials. In sum, Kirsner and Speelman controlled for task practice and so found that repetition priming did not change with increased repetitions. It was revealed that repetition priming occurred only after a single presentation of a repeated (old) word and that priming did not increase with further presentations. This result was contrary to the empirical findings of Logan (1988; 1990) who took no account of task practice and consequently, Kirsner and Speelman suggested that task practice effects may have contributed to Logan's priming results.

Whilst Logan's (1990) and Kirsner and Speelman's (1996) research experiments differed on their methods of the measurement of repetition priming, they both used lexical decision as the task. However, they also differed on the type of presentation of their lexical decision task. Logan presented his experimental blocks of trials (i.e., the blocks of target repeated words) with a limited number of intervening items between these blocks. The intervening items comprised of blocks of new words and nonwords which were presented just once each during the testing stage. With 16 repetitions in 3 minutes, Logan's design was an extreme form of massed presentation. In contrast, Kirsner and Speelman's presentations of the target (old) words occurred at intervals of not less than 24 hours and hence there were many intervening experiences between the presentations of the target words. In this situation, the intervening items consist of other activities completed by the participant outside of the testing laboratory. Kirsner and Speelman used a form of spaced presentation with 7 experimental sessions presented on 7 successive days. It is possible then that the differing empirical results of Logan and Kirsner and Speelman may be explained by the effects of the type of presentation of their stimuli. That is, massed presentation, where a stimulus is repeated on successive trials without any other items intervening between the repetitions or with limited intervening items, such as in Logan's design (1988, 1990), or spaced presentation, where one or several items intervene between the repeated presentations of a stimulus, such as in Kirsner and Speelman's design (Ostergaard, 1998).

The Effect of Massed and Spaced Presentation on Repetition Priming and Practice

The majority of research into the massed -spaced presentation effect has involved motor tasks and little research has been conducted using implicit perceptual tasks (Challis & Sidhu, 1993). For many years, it was thought that spaced presentation was the most efficient method for training motor skills (McGeoch, 1931). A review of the literature by Adams (1987), however, rejected this finding. Adams found that spaced practice did not improve learning relative to massed practice. Adams did find, however, that spaced practice improved the momentary level of performance but not the overall level of learning.

Adam's (1987) findings were not supported by a subsequent meta-analysis carried out by Lee and Genovese (1988). The meta-analysis of 47 studies determined that spaced presentation was superior to massed presentation when completing a simple motor task. Lee and Genovese refined their conclusions after completing further research in 1989. The later study used a movement timing task that involved two versions: a discrete version where the task was of short duration and had predefined start and stop points and a continuous version of longer duration and unknown start and stop times. The results showed a superior effect for massed presentation on the discrete task but a superior effect for spaced presentation on the continuous task. These findings have been further complicated by a subsequent meta-analytical review by Donovan and Radosevich (1999). Sixty-three studies with a mean weighted effect size of 0.46 revealed that the relationship between the type of presentation (massed or spaced) and performance is moderated by the nature of the task, the length of time between the spaced practice presentations and the interaction between the two variables. The results indicated that the optimal length of time between spaced presentations was related to the type of task being undertaken with longer intervals being more beneficial for complex non-motor tasks. These results indicate that the amount of time between spaced presentations can have a profound effect on the massed-spaced presentation effect.

Limited research has been conducted on the effect of type of presentation using implicit memory tasks (Cepeda, Pashler, Vul, Wixted & Rohrer, 2006; Russo, Mammarella & Avons, 2002). However, five studies did investigate the effect of massed presentation and spaced presentation on implicit memory tests. In general, it was found that massed presentation does not significantly increase the magnitude of priming over that with a single presentation of a primed stimulus (Challis & Sidhu, 1993; Greene, 1990; Jacoby & Dallas, 1981; Perruchet, 1989). Interestingly, when the presentations are spaced the conclusions are more confusing and contradictory. One set of studies was reported by Jacoby and Dallas (1981). They manipulated the spacing in two experiments using priming in the accuracy of perceptual identification as the implicit task. In both experiments, there was a small advantage for spaced items over massed items, although the effect was only significant for one of the experiments. Feustal, Shiffren and Salasoo (1983) reported a superior effect of spaced repetitions over massed repetitions in a word-identification task using a perceptual-clarification task, whereas Perruchet (1989) using the same implicit memory task, found a significant advantage for spaced presentations over massed in only one of four experiments. The inconsistency of results in these studies could be due to a lack of power as the number of participants ranged from 32 to 48 respectively.

To ensure sufficient power Greene (1990) completed a series of experiments investigating the spacing effect using three implicit memory tasks: spelling homophonic words, word-fragment completion and perceptual identification with a sample size ranging from 60 to 120 participants per experiment. Greene found an increase in priming for information presented at separate points in time (spaced presentation) for spelling homophonic words and word-fragment completion but not for information presented consecutively (massed presentation). However, an increase in priming was only found under intentional learning conditions for the perceptual identification task and not under incidental learning conditions involving the implicit memory.

Challis and Sidhu's (1993) findings supported the contradictory evidence presented so far on the effects of massed presentations and spaced presentations on implicit memory tasks. They found massed presentation did not increase priming on word fragment completion beyond that obtained from a single presentation (n=90).

In summary, it appears that repetition priming may be sensitive to changes in experimental design, such as the type of presentation of the stimulus (massed or spaced). However, it is also possible that other experimental factors are responsible for the difference in the magnitude of priming found during Logan's (1990) and Kirsner and Speelman's (1996) research, such as word frequency, task type and presentation context of the stimulus. A discussion of the underlying causes of the effect of these changes in experimental design on repetition priming is beyond the scope of this paper.

The Current Study

Previous research has attempted to resolve the effect of practice on repetition priming and also the effect of the type of presentation of the stimuli on repetition priming. The research has found support for the existence of an effect for massed versus spaced presentation. However, the findings are not conclusive. Repetition priming has been found to be sensitive to small variations in experimental design and thus the nature of the effect of intentionally manipulated variables may be clouded.

Furthermore, equivocal evidence has been found for the effect of practice on repetition priming. The empirical findings of Logan (1990) and Kirsner and Speelman (1996) are conflicting on the notion that repetition priming increases with practice. Indeed, according to Kirsner and Speelman, the effect of massed versus spaced presentations may moderate the influence of practice on priming.

The current study aimed to examine whether there is a massed/spaced effect on repetition priming as suggested by Logan's (1990) and Kirsner and Speelman's (1996) results. The effect of practice on repetition priming and whether this effect is moderated by the type of presentation (massed/spaced) of the stimuli was also addressed.

A lexical decision task was used in the present study, with a group of 20 words (old words) being repeated three times within the experiment with varying amounts of intervening items presented between each repetition of the old words. The intervening items comprised new words and nonwords. Given that Logan's (1990) research indicated that priming increases with increasing repetitions of a target word, it was expected that the amount of priming would increase with increasing repetitions. Also, given the conflicting empirical results for Logan (1990) and Kirsner and Speelman (1996), it was expected that the extent of priming, and in particular, the effect of extra repetitions on priming, would be affected by the spacing of the repetitions. It was anticipated that as the spacing increased, the amount of increase in repetition priming that occurs with increased repetition would be reduced.

Method

Participants

A convenience sample of 60 (40 females, 20 males) participants took part in the study, including 30 (23 females, 7 males) undergraduate students from Edith Cowan University, Perth and 30 members of the general public comprising 14 males and 16 females. The participants' ages ranged from 20 years old to 75 years old. Ethics approval was granted by the Human Research Ethics Committee of Edith Cowan University and each participant gave written consent on the day of testing. Participation was on a voluntary basis and all details and data collected remained confidential. The participants were informed that they could withdraw at any stage of the experiment. The participants from the Edith Cowan University's Psychology School's Research Participant Register ($n = 30$) were entered into a raffle for a $50 cash prize. The participants from the general public ($n = 30$) were offered no inducement.

All participants had English as their first language and normal or corrected-to-normal vision. The participants had not participated in a lexical decision experiment previously.

The participants were randomly assigned to one of three experimental conditions (Massed Presentation; Spaced Presentation; Superspaced Presentation) each comprising 20 participants.

Research Design

This study was a 3 x 3 x 2 (Type of Presentation x Amount of Experimental Practice x Word Type) mixed experimental design.

Each session comprised three experimental practice blocks of trials (E1 – E3) and six control practice blocks of trials (C1 – C6). Each of the three experimental blocks of trials (E1

– E3) consisted of 20 repeated 'old' words, 20 'new' words and 30 nonwords. Each control block (C1-C6) consisted of 40 'new' words and 30 nonwords. No 'new' word or nonword was repeated throughout the test session. A diagram of the stimulus presentation is shown in Appendix A.

The control blocks and the experimental blocks were presented in a pre-determined order. The 70 trials within each experimental and control block were presented in a random order. This design ensured that all participants had an equal amount of task practice before completing the final experimental block (E3).

The first independent variable was the type of presentation of the blocks of trials (Presentation), comprising three levels: (1) Massed Presentation condition in which blocks C1 – C6 were presented followed by blocks E1, E2 and E3 respectively, (2) Spaced Presentation condition in which blocks C1 – C4 were presented, followed by block E1, C5, E2, C6 and E3 respectively and (3) Superspaced Presentation condition in which blocks C1 and C2 were presented followed by E1, C4, C5, E2, C5, C6 and E3 respectively. A diagram of the stimulus presentation for each condition is shown in Appendix A.

The second independent variable was the amount of experimental practice (EP) comprising three levels: (1) Experimental Practice Block 1 (E1); (2) Experimental Practice Block 2 (E2); and (3) Experimental Practice Block 3 (E3).

The third independent variable was the word type comprising two levels: (1) New Word and (2) Old Word.

Two dependent variables were measured in the experiment: (1) reaction time (in milliseconds) on the correct 'word' response and (2) accuracy (%) of the lexical decision task.

The task performed was a lexical decision and all words/nonwords were presented in uppercase.

Materials

Three hundred and twenty low frequency words were selected with the following constraints: (1) frequency value of 1 per million words (Kucera & Francis, 1967); (2) 4 to 8 letters (inclusive) in length; and (3) no homophones or homographs were included (Appendix B).

Two hundred and seventy nonwords were generated by changing the letters of common English words until they were unrecognizable as English words (Appendix B). The nonwords complied with the above constraints and also conformed to English phonetic rules. None of the nonwords were generated from stimuli presented as words in the task.

Presentation of the lexical decision task and recording of the responses was controlled by Superlab software. The software was run on a Power Macintosh computer using a 17" monitor. Participants' responses were made on a standard computer keyboard.

Procedure

Testing was conducted in the Edith Cowan University's School of Psychology Memory and Cognition laboratory or using a laptop with participants working individually. The participant was seated at a computer and instructed that on each trial a letter string would appear on the screen in uppercase letters and that the letter string would remain on the screen until they made a response. The participant was told that they were to decide whether the letter string constituted a word or nonword. Participants indicated their decision by pressing the 'M' key on the lower row of the keyboard which was clearly marked 'WORD' or the 'Z' key clearly marked 'NONWORD'. The participant was instructed to complete each trial as quickly and as accurately as possible.

Overall, each participant completed 630 trials and each testing session took no longer than forty-five (45) minutes. The participants were given the opportunity to ask questions at the end of the test session.

Results

Results were analysed using the SPSS for Windows Graduate statistical package, Version 14.0. Reaction times *(ms)* that were equal to or greater than 5000 *ms* were deleted from the data set as were any incorrect responses. Priming values were calculated by two methods: (1) Kirsner and Speelman's (1996) method of subtracting reaction times of previously presented (old) words from the reaction times of the new words presented in the same block of trials ($RT_{new} - RT_{old}$) and (2) Logan's (1990) method of measuring the difference between the reaction time of the successive presentation of the repeated target word (old word) and the reaction time to the initial presentation of the target (old) word.

The data for each participant upon which the statistical tests were performed are included in Appendix C.

Accuracy

The percentage of correct responses to the old words [Accuracy *(%)*] was obtained for each participant (Appendix C). The resulting data were analysed using a 3 x 3 x 2 (Presentation x Practice x Word Type) Analysis of Variance (ANOVA). One outlying score (i.e., a score greater than three standard deviations from the mean of each condition) was detected during the screening of the data set and was deleted from each presentation condition. Mauchly's test indicated that the assumption of sphericity had been violated ($\chi^2(2) = 0.838, p < .05$). Therefore, the degrees of freedom were adjusted using Greenhouse-Geisser estimates of sphericity ($\varepsilon = .86$).

The results obtained indicated that there was a significant main effect for the amount of experimental practice, $F(1.72, 96.38) = 28.198, p < .05, \eta^2 = 0.085$ and a significant main effect for word type, $F(1.00, 56.00) = 50.605, p < .05, \eta^2 = 0.075$. The main effect for type of presentation was not significant, $F(2, 56) = 0.716, p > .05$.

There was a significant interaction of amount of experimental practice and type of presentation, $F(3.442, 96.386) = 2.916, p < .05, \eta^2 = 0.018$. Bonferroni –adjusted simple main effects analysis of the interaction revealed that there was a significant difference in accuracy across practice for Massed presentation, $F(3.442, 96.386) = 11.86, p < 0.025$, for Spaced presentation $F(3.442, 963.386) = 13.67, p < .025$ and for Superspaced presentation, $F(3.442, 96.386) = 18.47, p < .025$. The results for accuracy *(%)* across amount of practice and type of presentation are summarized in Table 1.

Table 1.

Accuracy (%) as a Function of Experimental Practice and Type of Presentation

	Mean Accuracy (%) for Type of Presentation					
Experimental Practice	Massed		Spaced		Superspaced	
	M	SE	M	SE	M	SE
E1	94.37	1.11	94.62	1.11	97.76	1.14
E2	91.62	1.21	89.75	1.21	91.05	1.24
E3	97.00	1.10	94.87	1.10	94.47	1.12

Post-hoc pair wise comparisons on the data for Massed presentation revealed that accuracy was significantly greater at practice level E3 than at practice level E2. No other significant differences were found for Massed presentation. The level of accuracy at practice level E1 and practice level E3 was significantly greater in both cases than at practice level E2 for Spaced presentation. No other significant differences were found for Spaced presentation. Post-hocs for Superspaced presentation revealed that the level of accuracy was significantly greater for practice level E1 than practice level E2 and E3. Also, the level of accuracy at practice level E3 was significantly greater than at practice level E2.

There was a significant interaction of experimental practice and word type, $F(1.951, 109.237) = 51.34, p < .05, \eta^2 = 0.145$. Bonferroni-adjusted simple main effects analysis of the interaction revealed that there was a significant difference in the level of accuracy across practice for new words, $F(1.951, 109.237) = 75.39, p < .025$ and a significant difference in the level of accuracy for old words, $F(1.951, 109.237) = 4.34, p < .025$. The results for accuracy *(%)* across amount of practice and word type are summarized in Table 2.

Table 2

Accuracy (%) as a Function of Experimental Practice and Word Type

	Accuracy (%)			
Experimental Practice	New Words		Old Words	
	M	SE	M	SE
E1	96.82	1.12	94.35	0.790
E2	85.00	1.08	96.62	0.64
E3	93.79	0.99	97.11	0.55

The level of accuracy for new words at practice level E1 was significantly greater than the level of accuracy at practice level E2 and E3 and the level of accuracy at E3 was significantly greater than the level of accuracy at E2.

The level of accuracy for old words was significantly lower at practice level E1 than practice levels E2 and E3 with the level of accuracy increasing with increasing practice. No other significant differences were found.

No significant effects were found for the interaction of type of presentation and word type, $F\ (1.95, 109.237) = 0.32, p > .05$ or for the interaction of the amount of experimental practice, word type and the type of presentation, $F\ (3.901, 109.237) = 0.23, p > .05$.

A one-way between groups ANOVA was carried out on the Accuracy scores at experimental practice E3 to determine the effect of the type of presentation on accuracy. The Accuracy scores at E3 were used to control for the amount of task practice. The ANOVA showed that the effect of type of presentation was significant on the level of accuracy at experimental practice E3, $F\ (2, 56) = 3.198, p < .05$. Detailed post-hoc analysis revealed that the level of accuracy was significantly greater for Massed presentation (M = 99.00 %, SE = 0.46 %) than Spaced presentation (M = 95.75 %, SE = 1.27 %). No other significant differences were found.

Mean Reaction Time Data (RT)

A 3 x 3 x 2 (Presentation x Experimental Practice x Word Type) ANOVA was performed on the mean reaction times (*ms*) for each participant (Appendix C). Two outlying scores (i.e., scores greater than three standard deviations from the mean of each condition) were detected during the screening of the data set and were deleted from each presentation condition. The assumptions of ANOVA were then deemed satisfactory.

There was a significant main effect for the amount of experimental practice, $F\ (2,110) = 4.661, p <.05, \eta^2 = 0.007$ and a significant main effect for word type, $F\ (1, 55) = 61.82, p<.05, \eta^2 = 0.020$. The main effect for type of presentation was not significant, $F\ (2, 55) = 0.406, p >.05$.

There was a significant interaction of amount of experimental practice and word type,

$F(2,110) = 17.84, p < .05, \eta^2 = 0.0018$. Bonferroni-adjusted simple main effects analysis of the interaction revealed that there was a significant difference in the RT across practice for new words, $F(2, 110) = 14.05, p < .025$ and a significant difference in the RT across practice for old words, $F(2, 110) = 11.23, p < .025$. Post-hoc pair wise comparisons on the data for new words only, revealed that the RT was found to be significantly faster for new words at practice level E1 (M = 1000.80 *ms*, SE = 26.33 *ms*) than for new words at practice level E2 (M = 1106.99 *ms*, SE = 42.57 *ms*) and the RT at practice level E2

(M = 1106.99 *ms*, SE = 42.57 *ms*) was significantly slower than the MRT at practice level E3 (M = 1027.21 *ms*, SE = 38.99 *ms*). However, the RT for new words presented at practice level E1 was not significantly different to the RT for new words presented at practice level E3. Figure 2 provides a graphical depiction of the effect of practice on RT for new words.

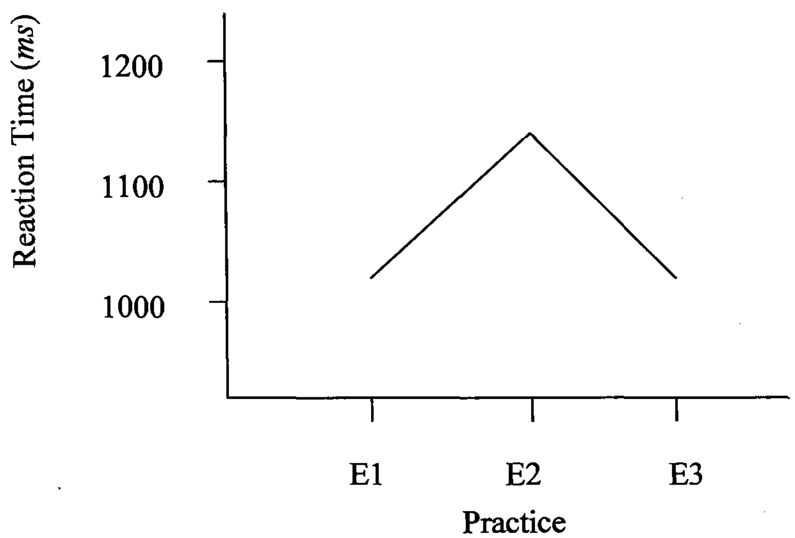

Figure 2. Reaction time (*ms*) as a function of practice for new words

Post-hoc comparisons for the old words only revealed that the RT decreased as the amount of practice increased (see Figure 3).

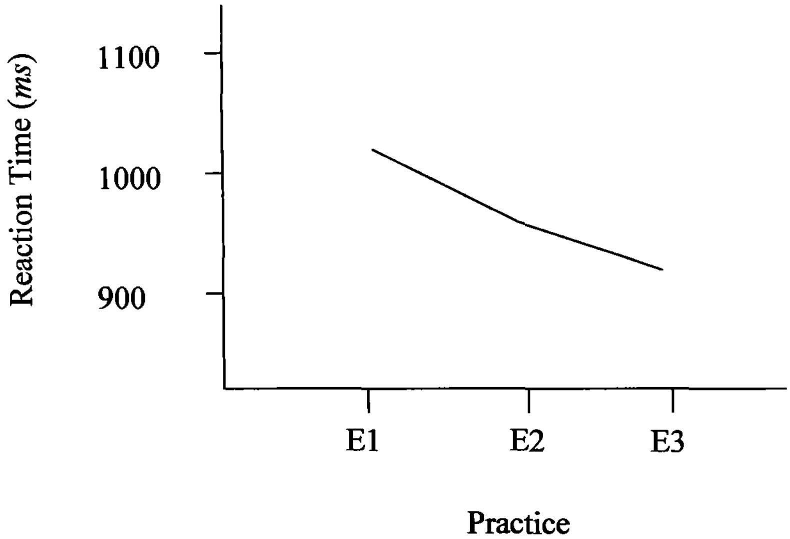

Figure 3. Reaction time (*ms*) as a function of practice for old words

Figure 3 shows that the RT at practice level E3 (M = 926.67 *ms*, SE = 31.01 *ms*) was significantly faster than at practice level E1 (M = 1023.83 *ms*, SE = 35.81 *ms*). The RT at E2 (M = 959.38 *ms*, SE = 32.26 *ms*) was significantly faster than the RT at practice level E1 (M = 1023.83 *ms*, SE = 35.81 *ms*). No other significant differences were found.

No significant effects were found for the interaction of type of presentation and the amount of experimental practice, $F\,(4,110) = 0.553, p > .05$ or for the interaction of the type of presentation, word type and the amount of experimental practice, $F\,(4,110) = 0.377, p > .05$.

A one-way between groups ANOVA was carried out on the E3 RT's for old words only to determine the effect of the type of presentation on the reaction times when the amount of task practice was equal for each participant. The ANOVA showed that the effect of the type of presentation was not significant for E3 RT OLD, $F\,(2, 55) = 0.259, p > .05$.

Mean Priming Value Data (PV)

Logan's (1990) Method. A 3 x 2 x 2 (Presentation x Experimental Practice x Word Type) ANOVA was performed on the mean priming values (*ms*) obtained using Logan's

(1990) method of calculation for each participant (i.e., the difference between the reaction time of the successive presentation of the repeated target word (old word) and the reaction time to the initial presentation of the target (old) word). Two outlying scores (i.e., scores greater than three standard deviations from the mean of each condition) were detected during the screening of the data set and were deleted from each presentation condition. The assumptions of ANOVA were then deemed satisfactory.

There was a significant main effect for experimental practice, $F(1, 55) = 4.67, p < .05, \eta^2 = 0.008$, with the PV at experimental practice E3 ($M = 97.16$ *ms*, $SE = 24.22$ *ms*) being greater than the PV at experimental practice E2 ($M = 64.45$ *ms*, $SE = 25.41$ *ms*) (see Figure 4).

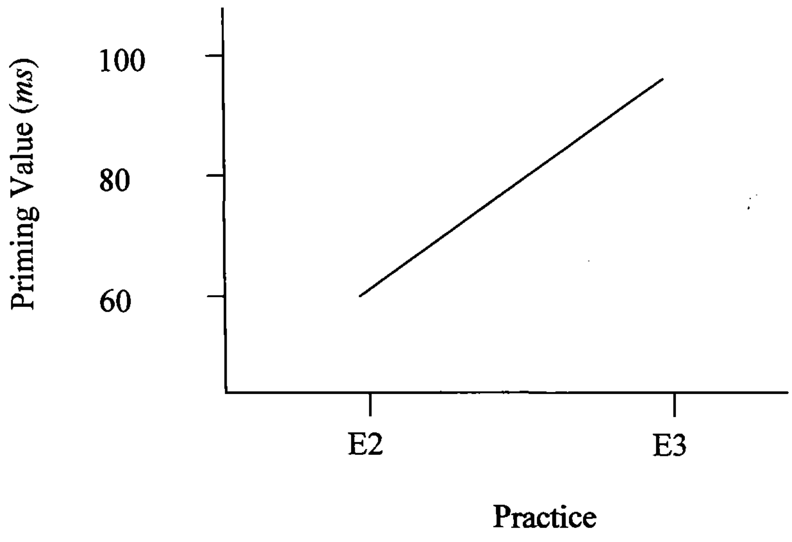

Figure 4. The effect of practice on mean priming values (*ms*) – Logan's method

No significant effect was found for the effect of the type of presentation, $F(2, 55) = 0.55, p > .05$ and no interaction effect was found for the interaction of the amount of experimental practice and the type of presentation, $F(2, 55) = 1.04, p > .05$.

A one-way between groups ANOVA was carried out on the PV at experimental practice E3 to determine the effect of the type of presentation on the amount of priming. The PV at E3 were used to control for the amount of task practice. The ANOVA showed that the effect for the type of presentation was not significant on the amount of priming at experimental practice E3, $F\,(2, 55) = 0.715, p > .05$.

Kirsner and Speelman's (1996) Method. A 3 x 2 x 2 (Presentation x Experimental Practice x Word Type) ANOVA was performed on the PV (*ms*) obtained using Kirsner and Speelman's (1996) method of calculation for each participant (i.e., subtracting reaction times of previously presented (old) words from the reaction times of the new words presented in the same block of trials) . Two outlying scores (i.e., scores greater than three standard deviations from the mean of each condition) were detected during the screening of the data set and were deleted from each presentation condition. The assumptions of ANOVA were then deemed satisfactory.

There was a significant main effect for type of presentation, $F\,(2, 55) = 3.17, p \leq .05$, $\eta^2 = 0.06$. No significant main effect was found for experimental practice, $F\,(1, 55) = 2.96, p > .05$ and no interaction effect was found for the interaction of the amount of experimental practice and the type of presentation, $F\,(2, 55) = 0.254, p > .05$.

As any effect of the type of presentation was relevant to the research question, further detailed post-hoc analyses of the significant main effect for the type of presentation were carried out. Post-hoc pair wise comparisons revealed that there was a significant difference in the amount of priming at experimental practice E2 between the Spaced presentation condition and the Superspaced condition, with the priming values for the Superspaced condition ($M = 206.17$ *ms*, $SE = 34.07$ *ms*) being greater than for the Spaced condition ($M = 93.63$ *ms*, $SE = 33.21$ *ms*). No other significant differences were found. The effect of presentation on mean priming values is shown in Figure 5.

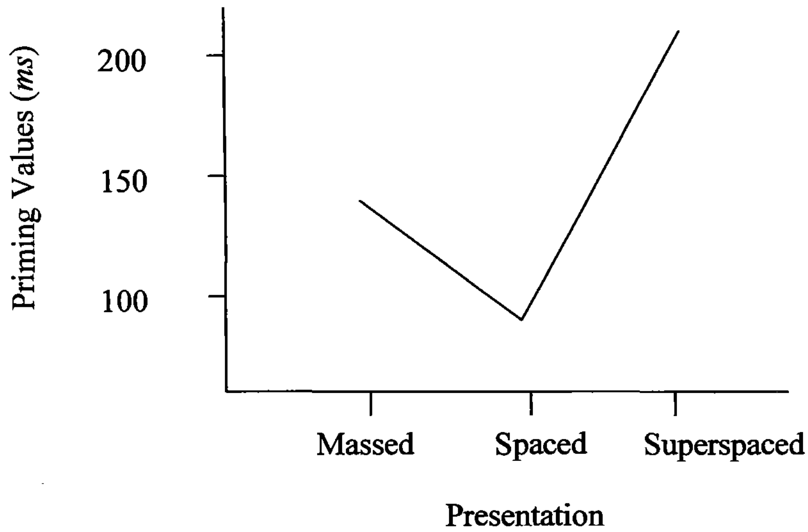

Figure5. Presentation effects on mean priming values (*ms*) – Kirsner and Speelman's method

A one-way between groups ANOVA was carried out on PV E3 to determine the effect of the type of presentation on the amount of priming. The PV at E3 were used to control for the amount of task practice. The ANOVA showed that the effect for the type of presentation was not significant on the amount of priming at experimental practice E3, $F(2, 55) = 1.038, p > .05$.

Discussion

The main findings were as follows: (1) The level of accuracy increased with increasing practice for old words. (2) The level of accuracy was affected by the type of presentation when task practice was controlled with the level of accuracy being greater for Massed presentation than for Spaced presentation. (3) The RT for new words increased on the second presentation of the experimental block of trials (E2) and decreased on the third presentation of the experimental block of trials (E3). (4) The RT for the old words decreased with increasing practice. (5) The RT at different amounts of practice was indifferent to the type of presentation. (6) The amount of priming increased with increasing practice when Logan's (1990) method of calculating priming values was used. (7) The amount of priming was indifferent to the type of presentation when Logan's method of calculating priming values was used. (8) The amount of priming was affected by the type of presentation when Kirsner and Speelman's (1996) method of calculating priming values was used, with the amount of priming for the Superspaced presentation being greater than the amount of priming for the Spaced presentation. (9) The amount of priming was indifferent to the type of presentation when task practice was controlled for both Logan's method of calculation and Kirsner and Speelman's method of calculation.

The Effect of Practice on Repetition Priming

The results of the study support the hypothesis that repetition priming would increase with increasing repetitions. It was found that the reaction time for the old words (i.e., the repeated target words) decreased as the amount of practice increased. Also, the amount of priming increased as the amount of practice increased when the priming values were calculated using Logan's (1990) method of calculation. Additionally, the level of accuracy increased significantly with increasing practice for the repeated old words. The observation that performance increased with practice is consistent with the theoretical position adopted by Logan. Logan's Instance Theory of skill acquisition states that repetition priming increases cumulatively with the number of times a word is presented in lexical decision. These findings would seem to provide additional support for the suggestion that performance on a task improves with practice.

The finding that performance increased with practice is also congruent with the theoretical position adopted by Kirsner and Speelman's (1996) Component theory of skill acquisition. The Component theory predicts that repetition priming increases with increasing practice. However, this result is inconsistent with the empirical findings of Kirsner and

Speelman's research which revealed that repetition priming occurred only after a single presentation of a repeated (old) word and that priming did not increase with further presentations. The present study found that there was no significant effect of practice on repetition priming when Kirsner and Speelman's method of measuring repetition priming was used. Kirsner and Speelman's measurement of repetition priming subtracted reaction times of previously presented (old) words from the reaction times of the new words presented in the same block of trials ($RT_{new} - RT_{old}$) thus controlling for task practice.

It is possible that there may have been a confounding order effect of the new words in each experimental block of trials which could have accounted for the lack of support for Kirsner and Speelman's (1996) empirical findings. The current study revealed that the reaction time for new words only, increased significantly on the second presentation of the experimental block of trials (E2) containing the 20 repeated old words. It then decreased to a reaction time similar to the reaction times of the initial presentation of the experimental block of trials (E1) upon the third presentation of the experimental block of trials (E3). Figure 2 depicts the effect of practice on the reaction time for new words. However, Figure 2 does not show typical improvement on a task with practice for new words. Typically, it would be expected that the reaction time would decrease for the lexical decision task with increasing practice as the participant becomes more proficient at completing the lexical decision task (i.e., task practice rather than item practice). As Kirsner and Speelman's measurement of repetition priming takes into account the reaction times to the new words in each experimental block of trials (E1 – E3), the lack of counterbalancing the words may have affected the magnitude of priming detected for experimental block E2. The significantly greater RT for the new words at E2 resulted in a greater magnitude of priming being detected at level E2 because the priming value at E2 was calculated by subtracting the RT of the old words presented at E2 from the RT of the new words presented at E2. The finding of the current study could have been caused by the use of the same 20 new words being presented in experimental block E1 for each condition, the same 20 words being presented in experimental block E2 for each condition and the same 20 new words being presented in experimental block E3 for each condition. For clarification, Appendix A shows the diagram of stimulus presentation. The lack of counterbalancing of the new words throughout the presentations of the blocks of stimulus trials may have contributed to the significantly greater RT detected at E2 for the new words. In any future research, the presentation of the new and nonwords used during the experiment should be counterbalanced over the presentation conditions (i.e., Massed, Spaced and Superspaced) to minimize any possible effect of the potential confounding variable.

There appears to be insufficient evidence to state whether the repetition priming detected conforms to the power law of learning as suggested by Logan (1990). Logan found that performance increased dramatically at the beginning of practice but as the lexical decision task proceeds and the amount of practice increases, improvement in performance becomes increasingly less (see Figure 1). The finding that the reaction time for old words decreased with increasing amounts of practice (see Figure 3) partially supported the power law of learning. That is, the performance for old words increased significantly between the initial presentation of block of experimental trials (E1) containing the 20 repeated old words and the second presentation of the experimental block of trials (E2) containing the 20 repeated words. The reaction time decreased on the third presentation of the experimental block of trials (E3) but the decrease was not a significant amount. It is suggested that if the number of repetitions of the old words is increased to greater than 3 (i.e., Logan (1990) presented 16 repetitions) in future research then evidence to support the power law of learning may be obtained.

The Effect of Massed and Spaced Presentation on Repetition Priming and Practice

The present data reveal that the type of presentation had an effect on the level of accuracy and on the mean priming values measured using Kirsner and Speelman's (1996) method. The level of accuracy was significantly greater for the Massed presentation condition than the Spaced presentation condition and the amount of priming was significantly greater for the Superspaced presentation condition than the Spaced condition. In addition, it was found that the type of presentation has no effect on reaction times or on the priming values (i.e., the priming values measured by Logan's (1990) method and Kirsner and Speelman's method) when the amount of task practice is controlled (i.e., the reaction times and priming values at E3 for old words only). These results for the priming values fail to support the hypothesis that as the spacing increases between repetitions, the amount of repetition priming that occurs with increased repetition would be reduced. Additionally, there is no support for the proposal by Kirsner and Speelman that the effect of massed versus spaced presentations may moderate the influence of practice on priming. The results indicate that it is possible the type of presentation of the stimuli may not actually have any effect on the amount of priming. It is possible that the differing empirical results of Logan and Kirsner and Speelman were in fact just due to the different methods used to calculate priming. Therefore, the differing presentation types used by the researchers may not account for the differing empirical results. If this is the case, then the differences found between the presentation types in this study may be assumed to be due to chance. This is supported by the fact that the differences found between the types of presentation seem to be inconsistent across the experiment.

Nevertheless, the results of the current study do indicate that a Massed-Spaced effect may exist as suggested by the empirical results of the research work of Logan and Kirsner and Speelman. The results of this study appear to add to the contradictory findings of the research work of Challis and Sidhu (1993), Greene (1990), Jacoby and Dallas (1981), Perruchet (1989) and Feustal, Shriffen and Salasoo (1983) on the effects of the Massed and Spaced presentation on implicit memory tasks.

The meta-analytical review by Donovan and Radesvich (1999) indicated that the optimal length of time between spaced presentations was related to the type of task being undertaken with longer intervals being more beneficial for improvement in performance on complex non-motor tasks. The current experiment used lists of new words and nonwords as the intervening items to create the spacing between the presentations of the control and experimental blocks of trials under the 3 conditions (see Appendix B). The time delay between the presentations of the experimental blocks of trials containing the 20 repeated old words in the current study was found to be relatively short when the testing was carried out as most participants completed the task (i.e., 9 blocks each comprising 70 trials) within 15 minutes. The limited number of intervening items between each repetition of the old words (i.e., the maximum number of intervening items between the repetition of the old words was 140 trials for the Superspaced condition) could have resulted in the participants having had no interference from other intervening items or experiences as was the case in Kirsner and Speelman's (1996) study where the participants were presented with the repetitions at a minimum of 24 hours apart. Consequently, the participants in Kirsner and Speelman's study would have had many intervening experiences between the repetitions associated with daily living including sleep. These additional intervening experiences may have contributed to the repetition priming detected. If the repetitions in this study were presented over a period of days as in the Kirsner and Speelman study then a significant effect for the type of presentation may be found thus providing further clarification of the Massed-Spaced effect.

Theoretical Implications

The current study was not designed to test Logan's (1990) Instance theory of skill acquisition and Kirsner and Speelman's (1996) Component theory of skill acquisition. The study aimed to determine if practice and the type of presentation had an effect on repetition priming as suggested by both theories and/or their empirical findings. Both theories predict that repetition priming will increase with practice on a task. However, the current study found that the amount of priming only increased with practice when Logan's method of calculating priming was used. There was no significant increase in the amount of priming with practice on the task when using Kirsner and Speelman's method of calculating priming. Given that no effect for practice was found when task practice was controlled as in Kirsner and Speelman's research, future studies could replicate or extend the current research ensuring that the new words and nonwords are counterbalanced over the conditions and that the repetitions are presented over a period of days as discussed previously. If an effect for practice was found using Kirsner and Speelman's method of calculating priming, it would provide additional evidence for the beneficial effect of practice on repetition priming. The future research should also assist in clarifying whether the Massed-Spaced presentation effect is in fact an issue.

The results of the current study imply that practice has a beneficial effect on implicit learning. It would appear that a person can never have too much practice on a task and that there is always room for further improvement on a task with practice. Such information may assist with the development of the existing knowledge base on the structure of the implicit memory and learning. However, further research is required to determine whether there is an advantage in implicit memory for information repeated at separate points of time (i.e, Spaced presentation) over information repeated in a Massed fashion.

In conclusion, the results of the experiment are consistent with the proposition that practice will improve performance on an implicit memory task. The study revealed that the amount of priming increased with increasing repetitions of a target word presented in a lexical decision task suggesting that there is always further improvement to be had with increasing practice. Also, it was determined that an effect for Massed-Spaced presentation may exist. However, the extent of the effect was not determined and it is possible that the type of presentation was not an issue. Future research is recommended to clarify any advantage of the type of presentation on an implicit memory task.

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Appendix A

Diagram of Stimulus Presentation

Massed Presentation

Blocks of Trials – Presentation Order

Block 1	Block 2	Block 3	Block 4	Block 5	Block 6	Block 7	Block 8	Block 9
C1	**C2**	**C3**	**C4**	**C5**	**C6**	**E1**	**E2**	**E3**
40 NEW WORDS	40 NEW WORDS	40 NEW WORDS	40 NEW WORDS	40 NEW WORDS	40 NEW WORDS	20 OLD WORDS	20 OLD WORDS	20 OLD WORDS
						20 NEW WORDS	20 NEW WORDS	20 NEW WORDS
30 NON WORDS	30 NON WORDS	30 NON WORDS	30 NON WORDS	30 NON WORDS	30 NON WORDS	30 NON WORDS	30 NON WORDS	30 NON WORDS

Spaced Presentation

Blocks of Trials –Presentation Order

Block 1	Block 2	Block 3	Block 4	Block 7	Block 5	Block 8	Block 6	Block 9
C1	**C2**	**C3**	**C4**	**E1**	**C5**	**E2**	**C6**	**E3**
40 NEW WORDS	40 NEW WORDS	40 NEW WORDS	40 NEW WORDS	20 OLD WORDS	40 NEW WORDS	20 OLD WORDS	40 NEW WORDS	20 OLD WORDS
				20 NEW WORDS		20 NEW WORDS		20 NEW WORDS
30 NON WORDS	30 NON WORDS	30 NON WORDS	30 NON WORDS	30 NON WORDS	30 NON WORDS	30 NON WORDS	30 NON WORDS	30 NON WORDS

Superspaced Presentation

Blocks of Trials – Presentation Order

Block 1	Block 2	Block 7	Block 4	Block 5	Block 8	Block 5	Block 6	Block 9
C1	**C2**	**E1**	**C4**	**C5**	**E2**	**C5**	**C6**	**E3**
40 NEW WORDS	40 NEW WORDS	20 OLD WORDS	40 NEW WORDS	40 NEW WORDS	20 OLD WORDS	40 NEW WORDS	40 NEW WORDS	20 OLD WORDS
		20 NEW WORDS			20 NEW WORDS			20 NEW WORDS
30 NON WORDS	30 NON WORDS	30 NON WORDS	30 NON WORDS	30 NON WORDS	30 NON WORDS	30 NON WORDS	30 NON WORDS	30 NON WORDS

Appendix B

List of Stimuli

LIST OF WORDS – NEW

BLOCK: PRACTICE

ALMOND	BEAD
COMPILE	DEEM
EXPIRE	GRACED
FATTEN	HYENA
JOUST	INFECT

BLOCK C1

UNRAVEL	FRILLY	PAGODA	ACIDITY
VOCALLY	GUTTER	QUARTZ	BUNNY
WALRUS	HARE	RIDDLE	COAX
YOGA	INDIGO	SMUGGLE	DEVIATE
ZONED	JOVIAL	TYPIFY	EAGERLY
AFFIX	KETCHUP	UNTIDY	FAUCET
BINGE	LUTE	VACCINE	GURGLE
CAVIAR	MAYHEM	WAND	HEARSE
DENTED	NUANCE	YODEL	IDOLIZE
ELAPSE	OUTCAST	ZOMBIE	JEWEL

BLOCK C2

FICKLE	TRAWLER	ENCHANT	PADDLE
KIOSK	UNBOUND	GRAPPLE	QICKEN
LIVID	VARNISH	HALTER	ROOFING
MAUVE	WRONGLY	IRATE	SILKY
NEURON	YOKE	JITTERY	TRICKY
OMIT	ZIPPER	KITE	UNPACK
PRIMATE	ANTIC	LAMENT	VACATE
QUIRK	COPIOUS	MENTOR	WICKET
REPRESS	BLUBBER	NOUN	YEARN
SHUN	DEFENCE	ORPHAN	ZEBRA

BLOCK C3

ABSTAIN	LICKING	VORTEX	HOIST
BREEZY	MASCARA	WOEFUL	INFLAME
CAVERN	NATURED	YONDER	JOSTLE
DUCT	OUTWIT	ASCEND	LAWSUIT
EMBODY	PERK	BOAR	MUMBLE
FLAKE	QUITS	CLOTTED	NIBBLE
GROAN	REDUCER	DINGHY	ONWARD
HUMID	SKIT	EXCLAIM	PARTOOK
IMPLANT	TINT	FIELDED	QUENCH
JOYFUL	UNSURE	GAUZE	REGAIN

BLOCK C4

SECLUDE	FERRET	REMARRY	ENVIOUS
TANDEM	GROVEL	SIZZLE	FINICKY

UPHILL	HEIRESS	TOIL	GANDER
VIBRATO	INHABIT	UPBEAT	HINGE
WHIMPER	JUMPER	VENDOR	INFLATE
ATONE	LAVA	WHACK	JEANS
BOOMING	MOULD	ADAPTER	LOBSTER
CARVER	NIGH	BOOKLET	METRE
DROWSY	OCTOPUS	CANTER	NUMERICAL
EVASION	PADDOCK	DRAUGHT	OVERRAN

BLOCK C5

OVEREAT	CHARMER	PARSLEY	DIESEL
PELVIS	DECEIVE	RADIATE	EXACT
RIFT	EXCEL	SLING	FAUNA
SEWN	FANCIER	TOPPLE	GLACIER
TAINT	TRUANT	UNSTUCK	HARDEN
UNPAVED	HELMET	VOYAGER	INFEST
VEAL	IMPERIL	WIGGLE	LOOPED
WEED	LOSER	ANIMATE	MALT
ANVIL	MAMMAL	BRACKET	NETHER
BONDING	NETTING	CUBE	PANTHER

BLOCK C6

RODEO	FEUD	TOUCHY	HEFTY
SHACK	GRAZE	UPSHOT	INFER
TICKING	HEXAGON	WILDER	LOADER
UPLIFT	IMPRINT	ASTHMA	MEATY
WALTZ	LURK	BARRACK	PERPLEX
ALLERGY	MAJESTY	CLENCH	RASH
BRAWL	NOSTRIL	DILUTE	SILO
CITRUS	PARCEL	EMPATHY	TRAUMA
DETACH	RACQUET	FLEE	UNEQUAL
EMPOWER	SIBLING	GRADING	WEASEL

BLOCK E1

DIGIT	INVADER	SNOUT	CEDAR
ENAMEL	LOGGER	TRIPLET	ENLARGE
FODDER	MELLOW	WASTAGE	SHRUB
GLOSS	PEBBLE	AURA	FELONY
HAGGLE	RASCAL	BRIBE	GIGGLE

BLOCK E2

HUMOUR	RUDDER	BAFFLE	GLUM
INSIPID	SEIZING	CARDIAC	HOSPICE
LODGED	THIMBLE	DURESS	INMATE
MASH	WHOOSH	EAVE	LABILE
PAMPER	ANCHOVY	FERN	MANIKIN

BLOCK E3

AMPLIFY	RAISIN	FUMING	FUNNEL
BRAINY	SHOPPER	PROLONG	REFRESH
CATCHY	TONGS	CANDLE	FUSING
FROTH	ANTHEM	SOLICIT	REFUTE
PRANK	BRED	AVERT	RUNT

LIST OF WORDS – OLD

BLOCKS E1 –E3

ARCHERY	FEMUR	MAGPIE	UNSCREW
BREWING	GASH	PAGEANT	WOMANLY
CAMEL	HOBBLE	RAMPAGE	ASTOUND
DIVERT	INTRUDE	SCUFFLE	BRAN
EMBRYO	LOTTERY	TOXIN	CARAMEL

LIST OF NON- WORDS

BLOCK PRACTICE

ANUMALY	TOIRET
HAMOUR	SUVKEN
INICLE	ULABLE
QUIB	WHOTE
REBUSE	ZIPLER

BLOCK C1

ATRICOT	PANNER	APPIAN
BADLE	RETH	BALLUS
CHAW	SEANCH	CHANK
DAULT	TAIXOR	DUVTY
HEENA	TRANEL	ELEZENT
INBENSE	UNARTED	FUTUME
LEVUL	VOGICA	GLAPE
MIVE	WEAT	HUTE
NERT	YOPE	IOCH
ORNAN	ZOME	JUVIPER

BLOCK C2

KNAT	UPBEAL	BISS
LUME	VOLEBLE	CORPETE
MESCIAN	WOTEN	DALED
NAUL	YOWS	EDENLY
OVIFORG	BOLL	FADDLE
QUIBBLE	ENLANGE	HARB
RODING	INHULAN	INOTIAL
SAGETY	GURCE	JOPIAN
TUBBAN	QUOM	KAL
PIRNIC	DWINKLE	GOOL

BLOCK C3

LIND	ANCHING	KANDLY
MUTISL	BESEINE	LINS
NOLOGY	COLBAT	MADREN
REVER	DUNLEON	NUGING
SNOFY	EMIL	OVIVE
THACKLE	FUPY	PANKS
USTAL	GUGGLE	QUILK
VOSE	HARKFUL	RULLBED
WROSE	ITYELF	SNABBED

ZEALET	JORIAL	TROP

BLOCK C4

UNCIFIL	JEWAL	ARPENIC
VULGAL	KAOWING	BALARE
WHECK	LEART	CUNICAL
YORDER	MOURD	DOTOR
BANDARE	NORVE	ESJORT
CRYNT	RIKUAL	FESERAL
DOSK	SCANNY	GUMNAST
FORRING	TIXIC	HEALTA
GEKIUS	UNBOIND	INFLAT
IPLAND	VIAZLE	JISTLE

BLOCK C5

KREAD	ARMURY	JEAMOUS
LIBETSL	BALNOON	KLACK
NOMPH	BORON	LAMER
ONSE	CURCASS	MURTARD
POCK	DIOL	NOPINEE
QUILOTE	EDUMATE	OBLITUE
RENG	FEVES	PRACE
SHINK	GADGAT	RUSTIC
TACKET	HANOR	SIFING
UNALARE	IBORY	QUEET

BLOCK C6

THEW	BAWTISM	KATHEN
URTERLY	CALERA	LURG
VOVAL	DRUNTEN	MEARE
WHOLA	EMBRAKE	NATURI
XYLEY	FENGAL	OUTLOME
YELLOF	GRAWE	POYSICS
ZESH	HALOC	QUARIFY
BEKE	IMLAND	RINNING
CORTAIL	JERIST	SECK
DOSCENT	USEM	TUBI

BLOCK E1

AKTHEM	GRONNY	NIGHTRY
BAEL	GOILT	OKOY
BASAFUL	HECRAICE	OPTOSE
BINCH	INPER	PAXAGON
CLIMP	JOMBLE	QUNICK
CLAFT	KADNEY	REACK
DEFICIT	KOYS	RIBBISH
ELAPTIC	LAPIE	SPUCE
ENCURE	MARSTRO	SUBSOAL
FORAVE	MORVOW	PRAVING

BLOCK E2

TONOR	AVIP	KNAWN
TIRSUE	BEFIND	LURKILY
UMPER	COPSULT	MAYLE
UNWARD	DINIT	NUTREG
WRECTED	ENDRIG	OZELET
XYNON	FRANE	PETLY
YOWTH	GRIMBLE	QUILTUS
ZORBIE	HELT	RABINE
ZONC	ISTUE	SHABING
WRONE	JODGE	TREN

BLOCK E3

BARTISM	JAWL	THERN
BARBUD	KEES	UNAIKED
BIGGING	LUZGAGE	VADUED
CIRWS	MOLUR	WODDED
DEVERSE	NEGITE	YOMEL
EKADE	ODINION	CHOER
FOAT	PIERRED	DUIL
GOLMEN	QUIPS	EXFORT
HIRKORY	RAME	LEBICAL
IMRART	SOCKEN	KREW

Appendix C

Raw Data Set

Mean Reaction Times (ms)

P	E1NEW	E1OLD	E2NEW	E2OLD	E3NEW	E3OLD
Massed						
1	1216.75	1206.94	1438.00	1053.94	1274.10	1154.25
2	831.30	772.16	924.20	825.16	825.30	775.35
3	1204.60	1392.20	1450.18	1069.80	1278.20	1031.75
4	1383.89	1920.56	2022.62	1789.21	1699.16	1999.16
5	985.84	1029.47	861.94	786.80	803.47	769.65
6	1399.84	1294.84	1772.18	1613.95	1442.45	1438.45
7	639.53	627.94	719.84	664.95	596.20	618.00
8	948.45	933.42	1063.37	966.50	948.05	884.00
9	782.10	815.37	888.94	788.95	788.20	797.75
10	1028.00	967.65	928.56	853.53	910.71	972.15
11	853.55	938.84	813.65	747.75	736.65	690.35
12	1146.95	1096.42	1402.95	1179.30	1223.50	948.35
13	1101.15	1167.10	1181.50	964.67	1074.53	949.05
14	1367.60	1846.28	1596.53	1309.70	1601.71	1197.15
15	860.20	814.22	856.71	903.11	914.28	746.55
16	991.95	972.53	1138.00	1038.10	907.63	911.70
17	1003.32	783.80	876.87	805.35	901.89	719.70
18	1245.00	1210.89	1222.00	1183.40	1410.20	1111.11
19	1002.67	861.00	1080.29	895.70	897.78	752.60
20	707.05	720.90	803.12	650.85	665.40	628.89
Spaced						
21	633.90	623.60	647.00	647.70	588.70	619.10
22	932.15	909.80	875.44	711.00	935.35	705.70
23	905.40	1147.80	1105.89	827.80	994.20	874.60
24	775.16	713.50	1159.72	1123.85	995.68	1169.00
25	975.70	860.65	994.79	1150.00	893.70	986.45
26	947.26	880.79	746.10	809.24	782.28	729.89
27	1052.85	1258.53	1319.67	1066.42	1267.40	1195.55
28	1326.55	1348.00	1194.14	1276.16	784.55	1058.00
29	819.95	1033.74	1033.95	769.80	803.30	762.75
30	1030.00	1291.24	1485.06	1133.16	1215.39	1058.00
31	1122.21	1589.00	1345.79	1012.45	901.68	995.63
32	818.05	888.25	985.83	981.15	1388.94	1088.35
33	1109.50	1391.67	1503.94	1205.24	1548.83	1497.89
34	723.60	744.74	809.53	788.15	792.55	803.84
35	1055.82	1121.65	934.00	929.27	1024.76	759.22
36	878.75	988.05	1051.61	923.75	1006.85	861.35
37	771.57	852.46	631.23	875.50	925.00	786.50

38	784.37	739.74	768.11	691.40	802.42	703.35
39	971.40	1247.95	1098.65	1002.47	1134.60	975.17
40	949.35	1092.95	975.94	869.28	912.06	875.53
Superspaced						
41	856.05	746.80	1158.50	784.45	808.25	776.00
42	1049.31	1062.29	1037.31	834.00	988.09	893.31
43	937.11	782.61	833.28	706.84	805.30	746.40
44	1098.50	1176.10	1194.29	965.15	1031.55	799.63
45	1014.90	1052.85	1251.40	886.00	808.89	791.75
46	960.37	954.45	1030.94	850.95	886.55	763.60
47	1117.65	966.53	1544.00	1489.85	1295.37	1040.11
48	834.95	778.90	852.83	704.68	765.26	810.35
49	1266.85	1013.79	1564.47	1088.61	1411.00	1160.83
50	1154.95	1137.15	1489.67	1239.42	1761.50	1045.16
51	1830.80	1953.37	2506.12	1957.89	1948.47	1940.47
52	1321.45	1251.32	1546.88	1138.63	1387.50	1032.11
53	1113.85	884.94	948.81	982.47	1615.75	1071.21
54	1200.95	1216.60	1408.29	1065.35	1232.15	1138.80
55	895.70	757.00	880.11	780.84	750.60	711.84
56	966.60	860.53	868.29	808.74	843.00	891.35
57	1064.10	1150.21	1075.67	868.50	1130.60	1036.11
58	882.60	951.47	796.86	829.79	767.50	826.59
59	938.47	901.89	955.22	845.55	976.89	832.65
60	891.50	871.16	1050.44	840.25	810.65	866.70

Accuracy (%)

P	E1NEW	E1OLD	E2NEW	E2OLD	E3NEW	E2OLD
Massed						
1	100.00	95.00	75.00	100.00	100.00	100.00
2	100.00	95.00	100.00	95.00	100.00	100.00
3	100.00	100.00	85.00	100.00	100.00	100.00
4	90.00	90.00	80.00	95.00	95.00	95.00
5	95.00	95.00	85.00	100.00	85.00	100.00
6	95.00	95.00	85.00	95.00	90.00	100.00
7	95.00	85.00	95.00	100.00	100.00	100.00
8	100.00	95.00	95.00	90.00	100.00	100.00
9	100.00	95.00	80.00	100.00	100.00	100.00
10	90.00	85.00	80.00	95.00	85.00	95.00
11	100.00	95.00	85.00	100.00	100.00	100.00
12	100.00	95.00	85.00	100.00	100.00	100.00
13	100.00	100.00	80.00	90.00	95.00	100.00
14	75.00	90.00	95.00	100.00	85.00	100.00
15	100.00	90.00	85.00	90.00	90.00	100.00
16	95.00	95.00	95.00	100.00	95.00	100.00
17	95.00	100.00	80.00	100.00	90.00	100.00
18	100.00	85.00	80.00	100.00	100.00	95.00
19	90.00	85.00	85.00	100.00	90.00	100.00

20	90.00	100.00	85.00	100.00	100.00	95.00
Spaced						
21	100.00	100.00	85.00	100.00	100.00	100.00
22	100.00	100.00	80.00	100.00	100.00	100.00
23	100.00	100.00	90.00	100.00	100.00	100.00
24	95.00	100.00	90.00	100.00	95.00	100.00
25	100.00	100.00	95.00	100.00	100.00	100.00
26	95.00	95.00	55.00	85.00	90.00	90.00
27	65.00	85.00	75.00	95.00	100.00	90.00
28	100.00	65.00	70.00	95.00	90.00	80.00
29	95.00	95.00	95.00	100.00	100.00	100.00
30	90.00	85.00	80.00	95.00	90.00	100.00
31	95.00	95.00	95.00	100.00	95.00	95.00
32	100.00	100.00	90.00	100.00	90.00	100.00
33	100.00	90.00	90.00	85.00	90.00	90.00
34	100.00	95.00	95.00	100.00	100.00	95.00
35	85.00	85.00	90.00	75.00	85.00	90.00
36	100.00	100.00	90.00	100.00	100.00	100.00
37	100.00	95.00	65.00	90.00	80.00	100.00
38	95.00	95.00	90.00	100.00	95.00	100.00
39	100.00	95.00	85.00	95.00	100.00	90.00
40	100.00	95.00	80.00	90.00	80.00	95.00
Superspaced						
41	100.00	100.00	90.00	100.00	100.00	100.00
42	85.00	85.00	80.00	95.00	55.00	65.00
43	95.00	90.00	90.00	95.00	100.00	100.00
44	100.00	100.00	85.00	100.00	90.00	95.00
45	100.00	100.00	75.00	100.00	95.00	100.00
46	95.00	100.00	90.00	100.00	100.00	100.00
47	100.00	95.00	85.00	100.00	95.00	95.00
48	100.00	100.00	90.00	95.00	95.00	100.00
49	100.00	95.00	75.00	90.00	70.00	90.00
50	100.00	100.00	90.00	95.00	100.00	95.00
51	100.00	95.00	80.00	95.00	75.00	95.00
52	100.00	95.00	85.00	95.00	100.00	95.00
53	100.00	90.00	80.00	95.00	80.00	95.00
54	100.00	100.00	85.00	100.00	100.00	100.00
55	100.00	95.00	90.00	95.00	100.00	95.00
56	100.00	95.00	85.00	95.00	100.00	100.00
57	100.00	95.00	90.00	100.00	100.00	95.00
58	100.00	95.00	70.00	95.00	80.00	85.00
59	95.00	95.00	90.00	100.00	90.00	100.00
60	100.00	95.00	90.00	100.00	85.00	100.00

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316–327.

Kučera, H., & Francis, W. N. (1967). *Computational analysis of present-day American English*. Providence, RI: Brown University Press.

Baddeley, A. D., & Hitch, G. J. (1974). Working memory. In G. H. Bower (Ed.), *The psychology of learning and motivation (Vol. 8)* (pp. 47–90). London: Academic Press.

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