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Assessing process dissociation procedure and implicit memory estimates of automatic retrieval for a retention interval manipulation

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Assessing Process Dissociation Procedure and Implicit Memory Estimates of Automatic Retrieval for a Retention Interval Manipulation

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Abstract

Results from standard implicit memory tests suggest that automatic retrieval decreases or remains relatively stable over time, whereas results from the process dissociation procedure (PDP) suggest that automatic retrieval may actually increase over time. Advocates of the PDP view, have suggested that this incongruity results from contamination of the implicit tests by intentional retrieval, whereas the PDP provides a valid index of automatic retrieval. In contrast, new results from a speeded implicit memory test suggest that the standard implicit memory tests provide reasonable estimates of automatic retrieval, but that the PDP underestimates automatic retrieval at a short retention interval when recollection is relatively high. The pattern of underestimation of automatic retrieval found for the PDP condition supports the conclusion that automatic retrieval and recollection are not independent, but rather are positively correlated.

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Introduction

On a typical implicit memory test, subjects first study or encode a list of stimulus materials, and later complete a task that tests the subjects' memory for the studied materials. However, in contrast to an explicit memory test, subjects are never instructed to intentionally retrieve the studied materials. Instead, memory is assessed by comparing test performance for studied versus non-studied material: An advantage for studied material is referred to as priming. Priming on the implicit test is commonly attributed to information acquired but not intentionally retrieved from the study phase (Schacter, 1987). Consequently, priming on implicit memory tests has been assumed to be a relatively pure index of automatic retrieval (e.g., Graf & Mandler, 1984). While intentional retrieval refers to the deliberate or conscious retrieval of studied materials, automatic retrieval refers to the unintentional retrieval of studied materials.

This assumption of the purity of implicit memory tasks has been questioned by several researchers (e.g., Jacoby, 1991; Reingold & Merikle, 1988, 1990; Richardson-Klavehn & Bjork, 1988; Toth, Reingold, & Jacoby, 1994; Toth & Reingold, 1996). These researchers have argued that many of the implicit memory tasks assumed to assess automatic retrieval may actually assess both automatic and intentional retrieval. Specifically, subjects may treat the implicit memory task like an explicit memory task and intentionally retrieve the studied materials.

The possibility that subjects may use intentional retrieval on an implicit memory task makes interpretation of implicit memory task performance difficult. For example, if an experimental manipulation (e.g., depth of processing) affects implicit memory task performance, the effect of the manipulation on retrieval processes is unclear — the experimental manipulation may be affecting automatic retrieval or intentional retrieval, or both.

Because of this difficulty in interpreting implicit memory task performance, Jacoby and colleagues have suggested that performance on a memory task typically reflects both automatic and intentional retrieval (Jacoby, 1991; Toth et al., 1994). Jacoby (1991) developed a procedure, termed the *process-dissociation procedure* (PDP), which he argues yields pure estimates of the contributions of automatic and intentional retrieval to performance on a memory task.

As on most explicit memory tasks, subjects in a PDP experiment first study a list of words and later are tested for their memory of those words. The PDP contains two conditions, *inclusion* and *exclusion*, which differ in the type of instructions given for the memory task. For an inclusion stem completion condition, subjects are instructed to try to complete the stem with a studied word; however, if they cannot recall a studied word, they are to respond with the first word that comes to mind. For an exclusion stem completion condition, subjects are instructed to complete the stem with a word that was not studied (Toth et al., 1994).

Before proceeding, the distinction between intentional retrieval and recollection should be highlighted. Intentional retrieval is used here to refer to the deliberate retrieval of a studied item, whereas recollection is used here to refer to conscious awareness that a retrieved item was studied. As will be discussed later, proponents of the PDP assume that intentional retrieval of a studied item always produces recollection, and automatic retrieval of a studied item never produces recollection (Jacoby, Toth, & Yonelinas., 1993; Toth et al., 1994).

Jacoby and colleagues assume that automatic retrieval and recollection provide independent bases of responding on the inclusion and exclusion tasks (Jacoby, in press; Jacoby et al., 1993; Toth et al., 1994). Only recollection allows for intentional responding; if a studied item is recollected, the subject is capable of 'including' or 'excluding' that item as a response on the memory task. In contrast, because automatic retrieval is assumed never to produce recollection, automatic retrieval does not allow for intentional responding; if a studied item is automatically retrieved, the subject is not capable of 'excluding' that item as a response. In sum, for the inclusion condition, responding at test with studied items is expected to occur when studied items are either automatically retrieved or recollected, whereas for the exclusion condition, responding with studied items is expected to occur only when studied items are automatically retrieved, but not recollected.

Figure 1 contains two Venn diagrams that illustrate the proportion of studied items expected to be included at test for inclusion and exclusion conditions. For each diagram, the area within the entire rectangle represents all studied items; the area within the circle labelled 'A' represents the proportion of studied items automatically retrieved, and the area within the circle labelled 'R' represents the proportion of studied items recollected. The Venn diagrams further illustrate the four possible cognitive states that are assumed to underlie responses on the inclusion and exclusion tasks. The area labelled '$A\bar{R}$' represents the proportion of studied items automatically retrieved but not recollected. The area labelled '$\bar{A}R$' represents the proportion of studied items recollected but not automatically retrieved. The area labelled 'AR' represents the proportion of studied items automatically retrieved and recollected. Finally, the area labelled '$\bar{A}\bar{R}$' represents the proportion of studied items neither automatically retrieved nor recollected.

For the inclusion condition, it is assumed that the probability of responding with a studied item, p(Inclusion), is equal to the sum of the following probabilities — the probability that a studied item is: (1) recollected but not automatically retrieved, $p(\bar{A}R)$, (2) automatically retrieved and recollected, p(AR), and (3) automatically retrieved but not recollected, $p(A\bar{R})$. Mathematically, this probability can be written as:

$$p(\text{Inclusion}) = p(\bar{A}R) + p(AR) + p(A\bar{R}) \qquad (1)$$

Note that the unconditional probability that a studied item is recollected, p(R), is equal to the sum of the probability that a studied item is recollected but not automatically retrieved, $p(\bar{A}R)$, and the probability that a studied item is both automatically retrieved and recollected, p(AR), as in Equation 2:

$$p(R) = p(\bar{A}R) + p(AR) \qquad (2)$$

Therefore, for the Inclusion condition, the probability of responding with a studied item is equal to the sum of the unconditional probability that a studied item is recollected, p(R), and the probability that a studied item is automatically retrieved but not recollected, $p(A\bar{R})$, as in Equation 3:

$$p(\text{Inclusion}) = p(R) + p(A\bar{R}) \quad (3)$$

For the Exclusion condition, responding with studied items is expected to occur only when studied items are automatically retrieved, but not recollected. Therefore, it is assumed that the probability of responding with a studied item, p(Exclusion), is equal to the probability that a studied item is automatically retrieved but not recollected, $p(A\bar{R})$. Mathematically, this probability can be written as:

$$p(\text{Exclusion}) = p(A\bar{R}) \quad (4)$$

Estimates of automatic retrieval and recollection are attained by comparing the proportion of studied items included in the Inclusion and Exclusion conditions. By subtracting the Exclusion equation (3) from the Inclusion equation (2) and solving for 'p(R)', the unconditional probability that a studied item is recollected, p(R), can be estimated by:

$$p(R) = p(\text{Inclusion}) - p(\text{Exclusion}) \quad (5)$$

That is, the probability that a studied item is recollected, p(R), can be estimated by the probability of including a studied item on the inclusion task, p(Inclusion), minus the probability of including a studied item on the exclusion task, p(Exclusion).

Jacoby and colleagues make a key assumption, which I will term the recollection assumption, concerning which retrieval processes result in recollection (Jacoby et al., 1993; Toth et al., 1994). According to the recollection assumption, there is a one-to-one mapping of intentional retrieval and recollection, such that intentional retrieval of a studied item always produces recollection, and automatic retrieval of a studied item never produces recollection. Therefore, the probability that a studied item is intentionally retrieved, p(I), is assumed to be equal to the probability that a studied item was recollected, p(R), as in Equation 6:

$$p(I) \doteq p(R) \quad (6)$$

To obtain an estimate of the unconditional probability of automatically retrieving a studied item, p(A), an algebraic manipulation of Equation 4 is required. Note that the product rule for conditional probabilities states that the probability that a studied item is automatically retrieved but not recollected, $p(A\bar{R})$, is equal to the product of the conditional probability that a studied item is automatically retrieved given that it is recollected, $p(A|\bar{R})$, and the unconditional probability that a studied item is not recollected, $p(\bar{R})$, as in Equation 7:

$$p(A\bar{R}) = p(A|\bar{R})*p(\bar{R}) \qquad (7)$$

Substituting Equation 7 into Equation 4 gives:

$$p(\text{Exclusion}) = p(A|\bar{R})*p(\bar{R}) \qquad (8)$$

By rearranging Equation 8, and noting that $p(\bar{R}) = 1 - [p(\text{Inclusion}) - p(\text{Exclusion})]$, it can be seen that the conditional probability that a studied item is automatically retrieved given that it is not recollected, $p(A|\bar{R})$, can be estimated in terms of the probabilities of including a studied item on the inclusion and exclusion tasks:

$$p(A|\bar{R}) = \frac{p(\text{Exclusion})}{1-[(p(\text{Inclusion})-p(\text{Exclusion})]} \qquad (9)$$

To estimate the unconditional probability that a studied item is automatically retrieved, p(A), a second key assumption is made. Automatic and intentional retrieval are assumed to be separate, parallel processes making independent contributions to inclusion and exclusion performance (Jacoby, 1991; Jacoby et al., 1993; Reingold & Toth, 1996; Toth et al., 1994), which I will term the retrieval independence assumption. The retrieval independence assumption necessitates that the probability of automatically retrieving a studied item is equivalent regardless of whether the studied item is intentionally retrieved. This probability can be written as:

$$p(A) = p(A|\bar{I}) = p(A|I) \qquad (10)$$

Recall that the recollection assumption states that there is a one-to-one mapping of intentional retrieval and recollection, such that intentional retrieval of a studied item always produces recollection, and automatic retrieval of a studied item never produces recollection. If automatic and intentional retrieval are assumed to be independent, and intentional retrieval is assumed to map perfectly on to recollection, then automatic retrieval and recollection must also be independent. Together, the retrieval independence and recollection assumptions necessitate that automatic retrieval and recollection make independent contributions to inclusion and exclusion performance, which is termed the independence assumption (Jacoby, 1991, in press; Jacoby et al., 1993; Reingold & Toth, 1996; Toth et al., 1994). The independence assumption necessitates that the probability of automatically retrieving a studied item is equivalent regardless of whether the studied item is recollected. This probability can be written as:

$$p(A) = p(A|\bar{R}) = p(A|R) \tag{11}$$

By making the independence assumption, the unconditional probability that a studied item is automatically retrieved, p(A), can be estimated from the conditional probability that a studied item is automatically retrieved given that it is not recollected, $p(A|\bar{R})$, as in Equation 12:

$$p(A) \doteq p(A|\bar{R}) = \frac{p(\text{Exclusion})}{1-[p(\text{Inclusion})-p(\text{Exclusion})]} \tag{12}$$

In sum, the PDP can estimate automatic and intentional retrieval, if the independence assumption is accepted.

Results from the PDP

The PDP has been used to determine the effects of a variety of variables on automatic and intentional retrieval. These variables include depth of processing (Toth et al., 1994), full versus divided attention at study (Jacoby et al., 1993), and aging (Jennings & Jacoby, 1993). For example, Toth et al. (1994, Experiment 1) manipulated depth of processing at study and estimated automatic and intentional retrieval from cued stem completion inclusion and exclusion tasks.

They found that the estimate of intentional retrieval for words that were semantically processed at study (.27) was greater than the estimate for words that were nonsemantically processed (.03). However, the estimate of automatic retrieval for semantically processed words (.42) was not significantly different from the estimate for nonsemantically processed words (.45). Based on these estimates, Toth et al. concluded that semantic processing of words has the same effect on automatic retrieval as does nonsemantic processing of words. Toth et al. also included an implicit memory stem completion test in this experiment. They found that stem completion performance was greater for semantically processed words (.51) than for nonsemantically processed words (.45). Because estimates from the PDP indicated that the depth of processing manipulation affects intentional retrieval but not automatic retrieval, Toth et al. concluded that the depth of processing effect found on the implicit memory test was attributable to contamination with intentional retrieval.

This conclusion is appropriate if the PDP provides valid estimates of automatic and intentional retrieval. However, the validity of the independence assumption used to produce these estimates has been questioned (Curran & Hintzman, 1995; Dodson & Johnson, 1996; Joordens & Merikle, 1993; Richardson-Klavehn & Gardiner, 1995, 1996; Richardson-Klavehn, Gardiner, & Java, 1996).

Questioning the Independence Assumption

Curran and Hintzman (1995) questioned the independence of automatic retrieval and recollection, which necessitates that $p(A) = p(A|R) = p(A|\bar{R})$. They suggested that automatic retrieval and recollection are not independent, but rather are positively correlated, which I will term the correlation hypothesis (see also Joordens & Merikle, 1993). Positive correlation of automatic retrieval and recollection would necessitate that the conditional probability of automatically retrieving a studied item given that it is recollected, $p(A|R)$, is greater than the conditional probability of automatically retrieving a studied item given that it is not recollected, $p(A|\bar{R})$, as in Equation 13:

$$p(A|R) > p(A|\bar{R}) \tag{13}$$

To see how a positive correlation of automatic retrieval and recollection would affect the PDP's estimates of automatic retrieval, it is useful to look at the general equation for determining the unconditional probability of automatic retrieval. The unconditional probability that a studied item is automatically retrieved, $p(A)$, is equal to the sum of the probability that a studied item is both automatically retrieved and recollected, $p(AR)$, and the probability that a studied item is automatically retrieved but not recollected, $p(A\bar{R})$, as in Equation 14:

$$p(A) = p(AR) + p(A\bar{R}) \tag{14}$$

The probability that a studied item is automatically retrieved but not recollected, $p(A\bar{R})$, is equal to the product of the conditional probability that a studied item is automatically retrieved given that it is not recollected, $p(A|\bar{R})$, and the unconditional probability that a studied item is not recollected, $p(\bar{R})$ (see Equation 7). Similarly,

$$p(AR) = p(A|R)*p(R) \tag{15}$$

Then, as described by Buchner, Erdfelder, and Vaterrodt-Plünnecke (1995), the unconditional probability that a studied item is automatically retrieved, $p(A)$, can be defined as:

$$p(A) = p(A|R)*p(R) + p(A|\bar{R})*p(\bar{R}) \tag{16}$$

As stated earlier, the estimate of unconditional automatic retrieval (Equation 12) depended on the assumption that $p(A) = p(A|\bar{R})$.[1] As can be seen from Equation 16, if the independence assumption is wrong and automatic retrieval and recollection are positively correlated such that $p(A|R) > p(A|\bar{R})$, then in general the unconditional probability that a studied item is automatically retrieved, $p(A)$, will be less than the conditional probability that a studied item is automatically retrieved given that it is recollected, $p(A|R)$, and greater than the conditional probability that a studied item is automatically retrieved given that it is not recollected, $p(A|\bar{R})$, as in Equation 17:

$$p(A|\bar{R}) < p(A) < p(A|R) \quad (17)$$

Consequently, the estimate of automatic retrieval derived from the PDP, $p(A|\bar{R})$, will underestimate unconditional automatic retrieval, $p(A)$.

Furthermore, as can be seen from Equation 16, the PDP's underestimation of automatic retrieval will increase as recollection increases (Curran & Hintzman, 1995). At one extreme, when the probability that a studied item is recollected, $p(R)$, approaches zero, the unconditional probability that a studied item is automatically retrieved, $p(A)$, will approach the conditional probability that a studied item is automatically retrieved given that it is not recollected, $p(A|\bar{R})$ (see Equation 16). It can be argued that, when there is little recollection of studied items, the PDP will provide a reasonably good estimate of unconditional automatic retrieval.

However at the other extreme, when the probability that a studied item is recollected, $p(R)$, approaches one, the unconditional probability that a studied item is automatically retrieved, $p(A)$, will approach the conditional probability that a studied item is automatically retrieved given that it is recollected, $p(A|R)$ (see Equation 16). Therefore, when recollection of studied items is close to perfect, the PDP's underestimation of unconditional automatic retrieval, $p(A)$, will be approximately the difference between the conditional probability that a studied item is automatically retrieved given that it is recollected, $p(A|R)$, and the conditional probability that a studied item is automatically retrieved given that it is not recollected, $p(A|\bar{R})$. Critical to the present experiment is the conclusion that, if there is a positive correlation of automatic retrieval and recollection, then when recollection is high, automatic retrieval will be underestimated; however, when recollection is low, underestimation will be minimal.

Misinterpretations Caused by Underestimation

Memory experiments frequently contain an independent variable (e.g., depth of processing, level of attention, retention interval) with levels that are associated with different degrees of recollection. If, as predicted by the correlation hypothesis, automatic retrieval and recollection are positively correlated, then the PDP would be expected to differentially underestimate automatic retrieval for the different levels; the underestimation should be greatest for the level in which recollection is highest. If there is differential underestimation, automatic retrieval estimates derived from the PDP could result in a misinterpretation of the effect (or lack of effect) of an experimental variable on automatic retrieval.

For example, Stolz and Merikle (1995) used estimates from the PDP to examine the effects of retention interval on automatic retrieval and recollection. They reported that, whereas estimates of recollection decreased from a 2-minute to a 2-day retention interval, estimates of automatic retrieval actually increased (and then gradually decreased for the longest retention intervals). This increase in automatic retrieval with retention interval is in sharp contrast to findings from previous studies that have assessed automatic retrieval using implicit memory tests. On the basis of performance on implicit memory tests, some researchers report a significant decrease in automatic retrieval over time (e.g., Roediger & Blaxton, 1987; Roediger, Weldon, Stadler, & Riegler, 1992; Sloman, Hayman, Ohta, Law, & Tulving, 1988), whereas others report that automatic retrieval remains relatively stable over time (e.g., Jacoby & Dallas, 1981; Tulving, Schacter, & Stark, 1982).

Why do results from implicit memory tests suggest that automatic retrieval decreases over time, yet estimates derived from the PDP suggest that automatic retrieval can actually increase over time? There are two possible explanations for these apparently contradictory results. First, if the independence assumption is valid, it could be argued that the PDP provides an accurate estimate of automatic retrieval, but that priming on the implicit memory tests is contaminated with intentional retrieval. If estimates from the PDP are valid, Stolz and Merikle's (1995) results suggest that automatic retrieval can increase from a short to a long retention interval. If implicit memory tests are contaminated with intentional retrieval, contamination should be greater for a short than a long retention interval (because recollection should be higher for a short than a long retention interval), and thus, overestimation of automatic retrieval by performance on an implicit memory test should be greater for a short than a long retention interval. If overestimation of automatic retrieval is greater for a short than a long retention interval, then the estimate of automatic retrieval may be inappropriately high for the short retention interval, but reasonably accurate for the long retention interval. Therefore, implicit memory tests might falsely indicate that automatic retrieval decreases (e.g., Roediger & Blaxton, 1987) or remains stable (e.g., Jacoby & Dallas, 1981) over time, when automatic retrieval actually increases from a short to a long retention interval.

The second explanation questions the validity of the automatic retrieval estimates from the PDP. If the independence assumption is not valid, it could be argued that the PDP differentially underestimates automatic retrieval, and that priming on implicit memory tests provides an accurate estimate of automatic retrieval. If priming on implicit memory tests provides an accurate estimate of automatic retrieval, results suggest that automatic retrieval decreases or remains stable from a short to a long retention interval. If the independence assumption is not valid such that automatic retrieval and recollection are positively correlated, $p(A|\bar{R}) < p(A) < p(A|R)$, then the automatic retrieval estimate derived from the PDP, $p(A|\bar{R})$, should underestimate unconditional automatic retrieval, $p(A)$. Further, because recollection should be higher for a short than a long retention interval, underestimation of automatic retrieval should be greater for a short than a long retention interval. If underestimation of automatic retrieval is greater for a short than a long retention interval, then the estimate of automatic retrieval may be inappropriately low for the short retention interval, but reasonably accurate for the long retention interval. Therefore, the PDP might falsely indicate that automatic retrieval increases over time, when automatic retrieval actually decreases (e.g., Roediger & Blaxton, 1987) or remains stable (e.g., Jacoby & Dallas, 1981) from a short to a long retention interval.

In sum, the seemingly contradictory results from implicit memory tests which suggest that automatic retrieval decreases over time (e.g., Roediger & Blaxton, 1987) or remains relatively stable over time (e.g., Jacoby & Dallas, 1981), and from the PDP which suggests that automatic retrieval can increase over time (Stolz & Merikle, 1995), could be explained two ways. First, contamination of implicit memory tests with intentional retrieval could account for the discrepancy in results. Second, a violation of the independence assumption underlying the PDP could account for the discrepancy. The present study was designed to determine which of the two explanations for these contrasting results is correct.

Logic of Present Experiment

The present experiment examined the effects of retention interval on automatic retrieval. It was designed to assess whether: (1) performance on an implicit stem completion (SC) test overestimates automatic retrieval, specifically that the overestimation is greater for a short than a long retention interval; (2) Jacoby's PDP underestimates automatic retrieval, specifically that the underestimation is greater for a short than a long retention interval; and (3) automatic retrieval and recollection are independent.

The general logic of the experiment is as follows. Generate/Recollect (G/R) memory conditions were used to provide a test of automatic retrieval and a test of recollection for each study item. Subjects in the G/R conditions were first given a speeded implicit memory task to index automatic retrieval, p(A), followed by a recollection task to index recollection, p(R). To provide evidence that the speeded implicit memory task was not contaminated with intentional retrieval, response times on the speeded implicit memory task were compared to response times for a baseline condition that was designed to prevent intentional retrieval, and to an explicit memory condition that was designed to encourage intentional retrieval. Previous research in our lab supports the conclusion that this speeded task provides a relatively pure estimate of automatic retrieval (Horton, Wilson, Kirby, Nielsen, & Williams, 1997).

Having provided evidence that the speeded implicit memory task provided a valid index of unconditional automatic retrieval, p(A), priming on the speeded implicit memory task was compared with priming from a standard implicit memory condition, and with automatic estimates from a PDP condition. These comparisons were used to determine the validity of automatic retrieval estimates from the standard implicit memory task and the PDP. If priming on the standard implicit memory task overestimates automatic retrieval, p(A), and that overestimation is greater for the short than the long retention interval, whereas the PDP provides a valid index of automatic retrieval, then the conclusion will be that the standard implicit memory task is contaminated with intentional retrieval. If the PDP underestimates automatic retrieval, p(A), and that underestimation is greater for the short than the long retention interval, whereas the standard implicit memory task provides a valid index of automatic retrieval, then the conclusion will be that automatic retrieval and recollection are positively correlated.

To further assess whether automatic retrieval and recollection are independent, memory estimates from the G/R conditions and the PDP were compared. Because the G/R conditions measure automatic retrieval and recollection for each item, it was possible to estimate the conditional probabilities for automatic retrieval, $p(A|R)$ and $p(A|\bar{R})$. Because the automatic retrieval estimate from the PDP should reflect automatic retrieval conditionalized on no recollection, $p(A|\bar{R})$ (see Equation 9), the automatic retrieval estimates from the PDP were compared to the estimates of $p(A|\bar{R})$ from the G/R conditions. Furthermore, the estimates of recollection, p(R), from the PDP and from the G/R conditions were compared.

To avoid confusion in the following section, it should be stated that I do not assume that subjects use a generate/recognize strategy on the G/R conditions; rather, there are several retrieval strategies that could be used, and several retrieval processes that could underlie responses for the G/R conditions. Some of these retrieval strategies and processes will be discussed later.

If the estimates of $p(R)$ and $p(A|\bar{R})$ do not differ for the G/R and PDP conditions, then it is plausible that the retrieval processes were similar for the G/R and PDP conditions, and that other memory estimates for these conditions would be similar: Specifically, the estimate of $p(A|R)$ derived from the G/R conditions could also reflect $p(A|R)$ in the PDP condition. With this logic, estimates of $p(A|R)$ and $p(A|\bar{R})$ were compared for the G/R conditions to determine whether automatic retrieval and recollection were independent such that $p(A|R) = p(A|\bar{R})$, or whether they were positively correlated, such that $p(A|R) > p(A|\bar{R})$. If automatic retrieval and recollection are positively correlated for the G/R conditions, this would suggest that they may also be positively correlated for the PDP condition.

Specifics of The Present Experiment

All subjects completed a semantically cued stem completion (SC) study task.[2] For each item on the study task, subjects were presented with a three-letter stem (e.g., ELE) and a semantic cue (e.g., a large animal with a trunk). Subjects were to respond with a word (e.g., elephant) that began with the stem and made sense given the semantic cue. The words retrieved were the memory target words. The memory tests were completed either during the same experimental session as the study task, or 7 days later. There were six different SC memory test conditions. In a PDP condition, subjects completed both an inclusion and an exclusion memory task, using standard inclusion and exclusion instructions. In a standard implicit memory condition, subjects completed a standard implicit memory SC test. In a blocked generate/recollect (G/R) condition, subjects completed a speeded implicit memory SC test, and later completed a recollection test. In an item generate/recollect (G/R) condition, for each item, subjects provided a speeded automatic response, immediately followed by a recollection test. Finally, two speeded control conditions (baseline, explicit memory) were included to help determine whether the speeded responses in the G/R conditions were pure indices of automatic retrieval, or were contaminated with intentional retrieval.

Attaining a Pure Index of Automatic Retrieval. To test my hypothesis, it was necessary that a memory test be included that provided a relatively pure index of automatic retrieval. To accomplish this, subjects in both G/R conditions were encouraged to respond very quickly during the speeded implicit memory tasks to minimize use of intentional retrieval strategies (Horton et al., 1997). Subjects in the blocked G/R condition completed a study task, two trials of a speeded practice SC task, two trials of a speeded implicit memory SC test, and two trials of a recollection test. Subjects in the item G/R condition completed the identical tasks, except that the speeded implicit memory test and recollection test were not blocked but collapsed together; for each item, subjects completed the speeded implicit memory test followed by the recollection test, before the next item was presented.

None of the stems on the speeded practice SC task could be completed with a studied word, whereas half of the stems on the speeded implicit memory SC task could be completed with a studied word, and half with a non-studied target word. For subjects in the blocked G/R condition, the instructions were identical for the speeded practice and speeded implicit memory SC tasks: Subjects were instructed to complete each stem with the first word that came to mind and to respond as quickly as possible. For subjects in the item G/R condition, the instructions for the speeded implicit memory SC task differed in that these subjects were informed that some of the stems could be completed with studied items. However, they still were instructed first to respond automatically and quickly with the first word that came to mind for each item. They were instructed to make no effort to either respond with or not respond with study words. Only after they gave their quick response were they to try to retrieve the studied word. Response times to each stem were recorded for the speeded practice and speeded implicit memory tasks.

Because none of the stems on the speeded practice SC task could be completed with a studied word, an intentional retrieval strategy would seem fruitless (and possibly a hindrance). Therefore, it is unlikely that subjects used an intentional retrieval strategy on the speeded practice SC task. Therefore, response times on the practice task are assumed to reflect an automatic retrieval strategy. However, the speeded implicit memory SC task could be contaminated with intentional retrieval. For a stem completion test, it is undoubtedly more time-consuming to try to complete a stem with a studied word than to complete a stem with the first word that comes to mind. Assuming that intentional retrieval is more difficult than automatic retrieval, subjects who use intentional retrieval should take longer to respond than subjects who respond automatically (Richardson-Klavehn & Gardiner, 1995). Note that priming of studied words might lower response times for stems of studied words, but response times for stems of non-studied target words should not be affected. Therefore, for the speeded implicit memory task, only response times for stems of non-studied target words were analyzed. An increase in response times from the speeded practice to the speeded implicit memory SC task would indicate that subjects switched to an intentional retrieval strategy for the speeded implicit memory task. However, no change in the pattern of response times from the practice to the implicit memory task would indicate that subjects continued to use an automatic retrieval strategy for the speeded implicit memory task. A consistent pattern of response times from the practice to the implicit memory task would provide evidence that priming on the speeded implicit memory task provides a valid index of automatic retrieval.

To provide further evidence that priming on the speeded implicit memory task provides a valid index of automatic retrieval, response times on the speeded implicit memory task were compared to those in two speeded control conditions: (1) baseline, and (2) explicit memory. The baseline condition was designed to prevent intentional retrieval; the explicit memory condition was designed to encourage intentional retrieval.

Subjects in the baseline condition completed the identical study task, speeded practice task, and speeded implicit memory task, as subjects in the blocked G/R condition. The only difference was that the studied words were changed for the baseline condition so that, in essence, these subjects completed a study task and then four trials of a speeded practice SC task in which none of the stems could be completed with studied words. Because none of the stems could be completed with studied words, subjects were extremely unlikely to use an intentional retrieval strategy. Therefore, response times over the four trials should either remain relatively unchanged or should decrease because of practice with the task.

Subjects in the explicit memory condition completed the identical study task, and speeded practice task, as subjects in the blocked G/R condition. However, instead of completing a speeded implicit SC task, subjects in the explicit memory condition completed a speeded explicit memory SC task. After the speeded practice task, subjects in the explicit memory condition were instructed to try to complete the remaining stems with studied words, while still trying to respond as quickly as possible. The use of intentional retrieval on the test trials should cause response times to be longer for the speeded test trials than the speeded practice trials.

If the pattern of response times for the speeded implicit memory tasks of the G/R conditions is similar to that of the baseline condition in which an intentional retrieval strategy was highly unlikely, but different from the explicit memory condition in which an intentional retrieval strategy was highly likely, then this will provide evidence that subjects in the G/R conditions did not use intentional retrieval. Critically, this result would support the conclusion that priming on the speeded implicit memory task provides a valid index of automatic retrieval.

Estimates of Automatic Retrieval. If the response time data support the conclusion that the speeded implicit memory task provides a valid index of automatic retrieval, then priming on the speeded implicit memory tasks will provide a benchmark with which priming on a standard implicit memory task and automatic estimates from a PDP can be compared.

If priming effects for the standard implicit and speeded implicit SC tasks are similar, this will suggest that the standard implicit memory task is not contaminated with intentional retrieval, and that the standard implicit memory task also provides a valid index of automatic retrieval. If priming is greater on the standard implicit task than on the speeded implicit SC task, this will indicate that the standard implicit memory task is contaminated with intentional retrieval. Further, if the overestimation is greater for the immediate than for the 7-day retention interval, then it will be concluded that intentional retrieval contamination of the standard implicit task is highest when recollection is highest.

If automatic estimates from the PDP are similar to priming on the speeded implicit SC tasks, this will indicate that the PDP provides a valid index of automatic retrieval. If automatic estimates from the PDP are less than priming on the speeded implicit SC tasks, this will indicate that the PDP underestimates automatic retrieval. Furthermore, if the underestimation is greater for the immediate than for the 7-day retention interval, then it will be concluded that underestimation of automatic retrieval by the PDP is highest when recollection is highest. Further, this pattern of underestimation will support the conclusion that automatic retrieval and recollection are not independent, but rather are positively correlated (Curran & Hintzman, 1995).

It should be noted that for the 7-day retention interval, recollection is expected to be low. When recollection is low, intentional retrieval contamination of the standard implicit memory test should be minimal. Similarly, when recollection is low, automatic retrieval estimates from the PDP should only minimally underestimate automatic retrieval.

Generate/Recollect Conditions. Following the speeded implicit SC task, subjects in the blocked G/R condition completed a recollection test. For the recollection test, each of the stems from the speeded implicit SC task was presented again, along with each of the subject's "quick responses" from the speeded implicit SC task. For each item, a subject answered one or two questions. The first question asked subjects to indicate whether their quick response was a previously studied word. If the quick response was not identified as a studied word, then the second question asked subjects to try to recall the studied word.

The PDP assesses both automatic retrieval and recollection of a study word at the same time. However, for a study word in the blocked G/R condition, automatic retrieval is assessed during the speeded implicit memory task, and recollection is assessed later during the recollection task. It is difficult to know how separating automatic and intentional retrieval over time will affect the retrieval process. Consequently, estimates of recollection and automatic retrieval conditionalized on no recollection from the blocked G/R and PDP conditions may not be equivalent for reasons other than the use of different retrieval strategies. Consequently, the item G/R condition was included. The item G/R condition assesses automatic retrieval and recollection at the same time, though separate memory tasks are still used.

Subjects in the item G/R condition were told that some of the stems could be completed with target words from the study phase. For each item, they were instructed first to respond automatically and quickly with the first word that came to mind. They were instructed to make no effort to either respond with or not respond with target words from the study task. After they gave their quick response, subjects answered the same untimed recollection questions, as subjects in the blocked G/R condition.

Comparing the PDP and G/R Conditions. The independence assumption states that automatic retrieval and recollection are independent, such that the conditional probability that a studied word is automatically retrieved given no recollection, $p(A|\bar{R})$, is equal to the conditional probability that a studied word is automatically retrieved given recollection, $p(A|R)$, as in Equation 11. To further assess the validity of the independence assumption, memory estimates from the PDP were compared with estimates from the G/R conditions.

The PDP can estimate $p(A|\bar{R})$ as the proportion of studied words included on the exclusion task, but it cannot directly estimate $p(A|R)$ (Buchner et al., 1995). However, results from the G/R conditions can be used to estimate the conditional probability that a studied word is automatically retrieved given recollection, $p(A|R)$.

To provide evidence that $p(A|R)$ derived from the G/R conditions could also reflect $p(A|R)$ in the PDP condition, estimates of $p(R)$ and $p(A|\bar{R})$ were compared for the G/R and PDP conditions. If these estimates are similar, then it is plausible that the retrieval processes were similar for the G/R and PDP conditions, and that other memory estimates for these conditions are similar: Specifically, the estimate of $p(A|R)$ derived from the G/R conditions could also reflect $p(A|R)$ in the PDP condition.

For the G/R conditions, estimates can be calculated for each of the joint probabilities of automatic retrieval and recollection, $p(AR)$, $p(\bar{A}R)$, $p(A\bar{R})$, and $p(\bar{A}\bar{R})$. The probability that a studied word is automatically retrieved with recollection, $p(AR)$, can be estimated by the proportion of studied words that are automatically retrieved on the speeded implicit SC task with recollection on the recollection task. The probability that a studied word is not automatically retrieved with recollection, $p(\bar{A}R)$, can be estimated by the proportion of studied words that are not automatically retrieved on the speeded implicit SC task with recollection on the recollection task. The probability that a studied word is automatically retrieved with no recollection, $p(A\bar{R})$, can be estimated by the proportion of studied words that are automatically retrieved on the speeded implicit SC task without recollection on the recollection task. Finally, the probability that a studied word is neither automatically retrieved nor recollected, $p(\bar{A}\bar{R})$, can be estimated by the proportion of studied words that are not automatically retrieved on the speeded implicit SC task without recollection on the recollection task.

Estimates of recollection from the G/R conditions can be calculated by the sum of the probability that a studied word is not automatically retrieved with recollection, $p(\bar{A}R)$, and the probability that a studied word is automatically retrieved with recollection, $p(AR)$, as in

Equation 5. An estimate of the conditional probability that a studied word is automatically retrieved given no recollection, $p(A|\bar{R})$, can be calculated by dividing the probability that a studied word is automatically retrieved without recollection, $p(A\bar{R})$, by the sum of the probability that a studied word is automatically retrieved without recollection, $p(A\bar{R})$, and the probability that a studied word is not automatically retrieved without recollection, $p(\bar{A}\bar{R})$, as in Equation 18:

$$p(A|\bar{R}) = \frac{p(A\bar{R})}{p(A\bar{R}) + p(\bar{A}\bar{R})} \tag{18}$$

Similarly, an estimate of the conditional probability that a studied word is automatically retrieved given recollection, $p(A|R)$, can be calculated by dividing the probability that a studied word is automatically retrieved with recollection, $p(AR)$, by the sum of the probability that a studied word is automatically retrieved with recollection, $p(AR)$, and the probability that a studied word is not automatically retrieved with recollection, $p(\bar{A}R)$, as in Equation 19:

$$p(A|R) = \frac{p(AR)}{p(AR) + p(\bar{A}R)} \tag{19}$$

Estimates of recollection from the G/R conditions, $p(R)$, were compared with estimates of recollection from the PDP condition, calculated using Equation 5. Furthermore, because the automatic retrieval estimate from the PDP should reflect automatic retrieval conditionalized on no recollection, $p(A|\bar{R})$ (see Equation 12), automatic retrieval estimates from the PDP (calculated using Equation 12) were compared to estimates of $p(A|\bar{R})$ from the G/R conditions. If the estimates of $p(R)$ and $p(A|\bar{R})$ do not differ for the G/R and PDP conditions, then it is plausible that the retrieval processes were similar for the G/R and PDP conditions, and that other memory estimates for these conditions would be similar: Specifically, the estimate of $p(A|R)$ derived from the G/R conditions could also reflect $p(A|R)$ on the PDP condition.

With this logic, estimates of $p(A|R)$ and $p(A|\bar{R})$ were compared for the G/R conditions to determine whether automatic retrieval and recollection were independent such that $p(A|R) = p(A|\bar{R})$, or whether they were positively correlated such that $p(A|R) > p(A|\bar{R})$. If automatic retrieval and recollection are found to be independent for the G/R conditions, then evidence that the retrieval processes are similar for the G/R and PDP conditions would suggest that they may also be independent for the PDP condition, and would support the conclusion that the independence assumption is valid. However, if automatic retrieval and recollection are found to be positively correlated, this would suggest that automatic retrieval and recollection are also positively correlated for the PDP condition.

Correction for False Alarms

Recollection for the G/R conditions needs to be corrected for two types of response bias, or false alarms. First, when a studied word is automatically retrieved without recollection, there may be a response bias to indicate recollection. I assume that this response bias can be estimated by the probability of automatically retrieving a non-studied target word, and falsely indicating recollection, $p(AR_{false})$. Therefore, the probability of automatically retrieving a studied word and indicating recollection, $p(AR_{Response})$, is equal to the sum of the probability of automatically retrieving a studied word with true recollection, $p(AR)$, and the response bias, $p(AR_{false})$. Therefore, the probability of automatically retrieving a studied word with true recollection, $p(AR)$, can be estimated as in Equation 20.

$$p(AR) = p(AR_{Response}) - p(AR_{false}) \qquad (20)$$

To the same extent that the response bias falsely increases the estimate of $p(AR)$, the response bias falsely decreases the estimate of the probability of automatically retrieving a studied word without recollection, $p(A\bar{R})$. Therefore, the probability of automatically retrieving a studied word and indicating no recollection, $p(A\bar{R}_{Response})$, is equal to the probability of automatically retrieving a studied word without recollection, $p(A\bar{R})$, minus the response bias, $p(AR_{false})$. Therefore, the probability of automatically retrieving a studied word without recollection, p(AR), can be estimated as in Equation 21.

$$p(A\bar{R}) = p(A\bar{R}_{Response}) + p(AR_{false}) \quad (21)$$

The second type of response bias occurs when a studied word is not automatically retrieved. When a studied word is not automatically retrieved without recollection, there may be a response bias to indicate recollection. The same logic can be used to correct for this second type of response bias, producing estimates of the probability of not automatically retrieving a studied word with true recollection, $p(\bar{A}R)$, and of the probability of not automatically retrieving a studied word without recollection, $p(\bar{A}\bar{R})$:

$$p(\bar{A}R) = p(\bar{A}R_{Response}) - p(\bar{A}R_{false}) \quad (22)$$

$$p(\bar{A}\bar{R}) = p(\bar{A}\bar{R}_{Response}) + p(\bar{A}R_{false}) \quad (23)$$

These corrected estimates of the joint probabilities, p(AR), $p(A\bar{R})$, $p(\bar{A}R)$, and $p(\bar{A}\bar{R})$, were used in Equations 5, 18, and 19 to determine p(R), $p(A|\bar{R})$, and p(A|R) for the G/R conditions.

Method

Subjects

A total of 192 undergraduate students participated from the Wilfrid Laurier University subject pool. They received credit toward their final grade in a psychology course.

Design

Sixteen subjects were assigned to each of the 12 conditions formed by the factorial combination of the between-subjects factors *test type* (standard implicit memory, PDP, explicit memory, baseline, blocked generate/recollect, and item generate/recollect) and *retention interval* (immediate and 7-day). In addition, for the PDP condition, inclusion and exclusion memory tasks were administered within subjects.

Materials

A total of 156 words were used. None of the words were proper nouns. All of the words had straightforward spellings and unique three-letter stems. The 156 words were divided into 96 critical words, 24 filler words, 24 baseline condition study words, 4 study buffer words, 4 non-study buffer words, and 4 baseline condition study buffer words. See Appendix A for a listing of words and stem completion baseline rates. A pilot study was conducted with 30 subjects, who did not participate in the main experiment, to attain these baseline rates. Subjects in the pilot study were instructed to complete a list of 200 stems with the first word that came to mind; there was no study phase.

The 96 critical words were assigned to four lists of 24 critical words each. Each list had a mean stem completion baseline rate of 23 percent. For each subject, one list of critical words served as the study list, one as the non-study list, one as the trial 1 practice list, and one as the trial 2 practice list, with the assignment of these lists counterbalanced across subjects.

Each critical list was divided into two instruction lists of 12 words each. Mean stem completion baseline rates for instruction lists ranged from 22 to 24 percent. For each subject in the PDP condition, one study and one non-study instruction list was assigned to the inclusion condition and the other study and non-study instruction list was assigned to the exclusion condition. The assignment of study and non-study instruction lists was counterbalanced across subjects.

Each instruction list of 12 words was divided into two sub-lists of 6 words each. One sub-list from each study instruction list and one sub-list from each non-study instruction list were assigned to trial 1 of the test phase. The other sub-list from each study instruction list and the other sub-list from each non-study instruction list were assigned to trial 2 of the test phase. The assignment of sub-lists to each trial of the test phase was counterbalanced across subjects.

Study Phase. A total of 52 semantically cued three-letter word stems were individually presented during the study phase. For subjects in all but the baseline condition, the stems could be completed with the 24 study list words, 24 filler words, and 4 study buffer words. The study list and filler stems alternated until all 48 were presented. The presentation order of the filler stems was randomized for each subject. The presentation order of the 24 study list stems was block randomized. Each block of four items contained two stems from each study instruction list. Both the assignment of study list stems to blocks and the order of study list stems within blocks were randomized. The four study buffer stems and their presentation order were fixed such that two of the study buffer stems were presented at the beginning of the study phase, and two at the end. For subjects in the baseline condition, the presentation of stems was the same, except that the study list and study buffer words were replaced (only for the study phase) with the baseline condition study list and baseline condition study buffer words.

Practice Phase. In all conditions, the stems of the 'trial 1 practice list' words were presented during trial 1 of the practice phase, and the stems of the 'trial 2 practice list' words were presented during trial 2 of the practice phase. For each subject, presentation order of stems was randomized within each trial.

Test Phase. A total of 56 stems were presented during trials 1 and 2 of the test phase. These were the stems of the 24 study list words, 24 non-study list words, 4 study buffer words and 4 non-study buffer words. Two of the four study buffer stems and two of the four non-study buffer stems were presented at the beginning of trial 1. The other two study buffer stems and two non-study buffer stems were presented at the beginning of trial 2. The presentation order of buffer stems was fixed across subjects.

For trial 1 of the test phase, stems for 12 study and 12 non-study list words were presented. The presentation order of the 24 stems was block randomized. Each block contained one word from one sub-list of each study instruction list, and one word from one sub-list of each non-study instruction list. For trial 2 of the test phase, stems for the other 12 study and 12 non-study list words were presented. Presentation order was again block randomized such that each block contained one word from the other sub-list of each study instruction list, and one word from the other sub-list of each non-study instruction list. For both trials of the test phase, both the assignment of stems to blocks and the order of stems within blocks were randomized.

Post-Test Phase. Each subject in the blocked generate/recollect (G/R) condition was again presented with the 56 stems from the test phase and with his/her stem completion responses from the test phase. For trial 1 of the post-test phase, stems and stem completion responses for the 12 words from one study instruction list, and the 12 words from one non-study instruction list were presented. For trial 2 of the post-test phase, stems and stem completion responses for the 12 words from the other study instruction list, and the 12 words from the other non-study instruction list were presented. Consequently, for each trial of the post-test phase, half of the stems for study and non-studied words were previously presented during trial 1 of the test phase and half were previously presented during trial 2 of the test phase. For both trials of the post-test phase and for each subject, the study and non-studied words were block randomized. For each trial, each block of four items contained one word from each sub-list of the study instruction list, and one word from each sub-list of the non-study instruction list. For each subject, both the assignment of words to blocks and the order of words within blocks were randomized.

Each subject in the PDP condition was presented with the stems for the same 56 words (24 study list, 24 non-study list, and 8 buffer words) that were presented to subjects in the blocked G/R condition. However, because these subjects did not complete a test phase, they were not presented with responses from the test phase. Block randomization and presentation of the stems was identical to that for subjects in the blocked G/R condition.

All eight buffer stems (four study and four non-study buffer stems) presented during the test phase and the test phase responses for these stems were presented at the beginning of trial 1 of the post-test phase. The presentation order of buffer stems was fixed across all subjects.

Procedure

The general procedure for each test type condition is illustrated in Figure 2. The instructions given to subjects for each phase of the experiment are provided in Appendix B. Subjects were tested individually. Subjects in all but the PDP condition completed, in order, a study phase, filler task, practice phase, and test phase. Subjects in the blocked G/R condition also completed the post-test phase following the test phase. Subjects in the PDP condition did not complete the test phase, but did complete the post-test phase after the practice phase.

Subjects in the immediate retention interval conditions completed all phases of the experiment in one experimental session. Subjects in the 7-day retention interval conditions completed another filler task at the beginning of the experiment that was identical to the post-study filler task. Thus, in the initial experimental session, the 7-day subjects completed, in order, a filler task, study phase, and filler task. During the second experimental session that was scheduled seven days after the initial session, they completed the practice, test, and post-test phases as required by *test type* condition.

Study phase. Subjects in all *test type* conditions were given the same semantically cued stem completion study task. Each item on the study phase consisted of the presentation of the three-letter stem (e.g., ELE) of a study list word (e.g., elephant) and a semantic cue (e.g., a large animal with a trunk). Both the semantic cue and the stem were presented in the centre of a computer screen, with the three-letter stem three lines below the semantic cue. Subjects were instructed to respond with a target word that began with the stem and made sense given the cue. If the subject's response was correct, the experimenter pressed a key on the keyboard to present the next item. If the subject's response was incorrect, the experimenter gave the subject a second chance. If the subject still could not provide the correct response, the experimenter stated the correct answer, and pressed a key to present the next item. Subjects provided the correct response for 99.1 percent of the study items.

Practice Phase. The practice phase contained two trials. Each item on the practice phase trials consisted of the presentation of a three-letter stem in the centre of the computer screen. Subjects in the standard implicit memory and PDP conditions were instructed to complete each stem with the first word that came to mind. Subjects in all other conditions were instructed to complete each stem with the first word that came to mind *and* to respond as quickly as possible. A voice-activated relay recorded response times — the time from stem presentation to initiation of a verbal response. Following each practice trial, subjects were shown their average response time for that trial and any previous trial, and encouraged to try to go quicker on the next trial. The experimenter typed the response to each stem into the computer and pressed a key to begin the presentation of the next stem.

Test Phase. Following the practice phase, subjects were given trials 1 and 2 of the test phase. Identical to the practice phase, each item on the test phase consisted of the presentation of a three-letter stem in the centre of the computer screen.

Subjects in the standard implicit memory condition again were instructed to complete each stem with the first word that came to mind. Subjects in the blocked G/R and baseline conditions again were instructed to complete each stem with the first word that came to mind and to respond as quickly as possible. Subjects in the standard implicit memory and blocked G/R conditions were not informed that half of the stems could be completed with words from the study phase. Therefore, the instructions to subjects in the standard implicit memory, blocked G/R, and baseline conditions did not change from the practice to the test phases. In fact, to subjects in the standard implicit memory condition, these were simply the third and fourth trials of the stem completion task. Similarly, to subjects in the blocked G/R, and baseline conditions, these were simply the third and fourth trials of the speeded stem completion task.

Subjects in the item G/R condition were told that some of the stems could be completed with target words from the study phase. For each item, they were instructed first to respond automatically and quickly with the first word that came to mind. They were instructed to make no effort to either respond with, or not respond with, target words from the study task. After they gave their quick response, they were instructed to slow down and answer one or two questions, which were not timed. The first question was, 'Is your quick response the same as a target word from the study task?' If it was the same, they were to respond 'yes'; if it was not the same, they were to respond 'no.' If they responded 'yes,' the next item was presented. If they responded 'no,' they were to answer the question, 'If your quick response is not the same as a target word, can you remember what the target word was that began with that stem?' If they could remember the target word from the study phase, they were instructed to respond with that word. If they could not remember, they were to respond 'no.' Guessing was discouraged. At the end of an item, subjects were told to prepare to give a quick response to the next item. It was emphasised that for each item the first response was to be quick and automatic, and was not a test of their memory. Subjects were taken step-by-step through these instructions for the eight buffer items that preceded the test items, to ensure that they understood the instructions.

Subjects in the explicit memory condition were also told that some of the stems on the test phase could be completed with target words retrieved during the study phase. They were instructed to try to complete each stem with a target word they retrieved during the study phase, and still to respond as quickly as possible.

For the blocked G/R, baseline, and explicit memory conditions, response times were recorded. For the item G/R condition, only the response times for the first response to an item was recorded. Following trial 1 of the test phase, subjects were shown their average response time for that trial and both practice trials, and encouraged to try to go quicker on the last trial. All responses were typed into the computer. For subjects in the standard implicit memory, item G/R, explicit memory, and baseline conditions, the experimental session ended when the test phase was completed.

Post-test Phase. The post-test phase consisted of two trials. For subjects in the PDP condition, each item on the post-test phase consisted of the presentation of a three-letter stem in the centre of the computer screen, with either the word 'old' or 'new' three lines above. They were told that some of the stems presented during the post-test phase could be completed with target words from the study phase. Subjects were instructed that when the word "old" appeared above a stem, they were to try to complete the stem with a target word from the study phase. If they could not remember a study phase target word, they were to complete the stem with the first word that came to mind. When the word "new" appeared above a stem, they were to try to respond with the first word that came to mind that was not a study phase target word.

For subjects in the blocked G/R condition, all stems presented during the post-test phase were previously presented during the test phase. Each item on the post-test phase consisted of the presentation of a stem, along with the subject's "quick response" for that stem from the test phase. Each stem and response were presented in the centre of the computer screen, the latter one line below the former. For the first time, subjects were told that some of the stems presented during the test phase could have been completed with target words from the study phase. Subjects were instructed that for each item they were to answer one or two questions. The questions were the same as those given to subjects in the item G/R condition during their test phase.

Subjects were taken through the instructions step-by-step for the eight buffer items that preceded the test items, to ensure that they understood the instructions. Additionally, it was emphasised to subjects that their responses were not being timed. All responses were typed into the computer.

Filler Task. Subjects were instructed to solve the 'Tower of Hanoi' puzzle (starting with four pieces) as quickly as possible. If the puzzle was solved, it was repeated with an additional piece each time until approximately 7 minutes elapsed.

Results

An alpha level of .05 was adopted for all statistical tests.

Attaining a Pure Index of Automatic Retrieval

For each subject in the blocked generate/recollect (G/R), item G/R, baseline, and explicit memory conditions, median response times (length of time from presentation of the stem to beginning of a verbal response) were calculated for each of the two speeded practice stem completion (SR) trials and for non-studied words for each of the two speeded test trials. Table 1 presents the means of these median response times.

To determine whether subjects in the G/R conditions used an intentional retrieval strategy on the speeded implicit test trials, response times for stem completions for both G/R conditions were compared with response times for the baseline and explicit memory conditions. None of the stems presented during the baseline condition could be completed with a studied word. Therefore, subjects in the baseline condition were unlikely to engage intentional retrieval. In contrast, subjects in the explicit memory condition were likely to use intentional retrieval on the speeded explicit memory task. If subjects in the G/R conditions used intentional retrieval, then response times on the speeded implicit memory task for the G/R conditions should be greater than response times on the speeded test task for the baseline condition, but similar to response times on the speeded explicit memory task for the explicit memory condition. However, if subjects in the G/R conditions did not use intentional retrieval, then response times on the speeded implicit memory task for the G/R conditions should be similar to response times on the speeded test task for the baseline condition, but less than response times on the speeded explicit memory task for the explicit memory condition (Richardson-Klavehn & Gardiner, 1995).

A 4 X 4 X 2 mixed analysis of variance was conducted on median response times as a function of trial, test type, and retention interval. There were four trial conditions: (1) practice trial 1 stems, (2) practice trial 2 stems, (3) non-studied target stems presented during speeded test trial 1, and (4) non-studied target stems presented during speeded test trial 2. There were four test type conditions: (1) blocked G/R, (2) item G/R, (3) baseline, and (4) explicit memory. There were two retention interval conditions: (1) immediate, and (2) 7-day.

The three-way interaction was not significant, $F(9,360) < 1$, $MSE = 23215$. Also, the interactions between trial and retention interval, and between test type and retention interval, along with the effect of retention interval were not significant, $F(3,360) = 1.16$, $F(3,120) < 1$, $MSE = 95316$, and $F(1,120) < 1$, respectively, indicating that retention interval had no influence on response times.

Critical to the hypothesis, was the significant interaction of trial and test type, and significant main effects of both trial and test type, $F(9,360) = 22.60$, $F(3,360) = 22.98$, $F(3,120) = 11.92$, respectively. To aid interpretation of the interaction, an analysis of simple main effects was conducted. The simple main effect of test type for the trial 1 practice stems was not significant, $F(3,124) < 1$, $MSE = 17886$. Similarly, the simple main effect of test type for the trial 2 practice stems was not significant, $F(3,124) = 1.13$, $MSE = 24169$. However, the simple main effect of test type for the non-studied stems presented during trial 1 of the speeded test task was significant, $F(3,124) = 27.17$, $MSE = 70563$, as it was for non-studied stems presented during test trial 2, $F(3,124) = 14.87$, $MSE = 50390$.

To aid interpretation of the significant simple main effects for trials 1 and 2 of the speeded test task, linear contrasts were conducted. For trial 1 of the speeded test task, linear contrasts comparing the blocked G/R condition with the item G/R condition, and comparing the average of the G/R conditions with the baseline condition were not significant, both

*F*s(1,124) < 1. Similarly, for trial 2 of the speeded test task, linear contrasts comparing the blocked G/R condition with the item G/R condition, and comparing the average of the G/R conditions with the baseline condition were not significant, both *F*s(1,124) < 1. However, linear contrasts comparing the average of the baseline conditions and the G/R conditions with the explicit memory condition were significant for both trials 1 and 2 of the speeded test task, *F*s(1,124) = 80.54, 44.29, respectively.

In sum, these results indicate that subjects in all 4 conditions had similar response times for the speeded practice trials. However, response times for the speeded test trials for subjects in the baseline and G/R conditions were less than response times for the speeded test trials for subjects in the explicit memory condition (average of baseline and G/R conditions, test trial 1 = 847; average of baseline and G/R conditions, test trial 2 = 836; explicit memory, test trial 1 = 1334; explicit memory, test trial 2 = 1140).

These results suggest that for the speeded test trials, subjects in the baseline and G/R conditions used the same retrieval strategy, whereas subjects in the explicit memory condition used a different retrieval strategy. Assuming that subjects in the explicit memory condition used an intentional retrieval strategy, and subjects in the baseline condition did not use an intentional retrieval strategy, then by inference the evidence suggests that subjects in the G/R conditions did not use intentional retrieval on the speeded implicit memory task. Thus, these results support the conclusion that priming on the speeded implicit memory task provides a valid index of automatic retrieval

Non-studied Target Scores

Before analyses of priming and automatic retrieval can be conducted, an analysis of non-studied target words is required. For the inclusion condition, it is assumed that there is a baseline rate of responding, $p(B_{Inclusion})$, equivalent to the probability of responding on the inclusion task with a non-studied target item. A similar baseline rate of responding, $p(B_{Exclusion})$, is assumed for the exclusion condition. Toth et al. (1994) suggested that if automatic retrieval and recollection are independent, the baseline rates should be equivalent.

To test this, a 2 X 2 mixed analysis of variance was conducted on non-studied scores in the PDP condition as a function of instruction and retention interval. There were two levels of instruction: (1) inclusion, and (2) exclusion. Non-studied scores were calculated as the percent of non-studied target stems that were completed with non-studied target words. The mean non-studied scores are presented in Table 2. The analysis revealed no significant effects, all Fs < 1.04. These results indicate that baseline rates do not differ for the inclusion and exclusion instructions of the PDP condition.

Because inclusion and exclusion non-studied scores did not differ significantly, an average non-studied score of the inclusion and exclusion conditions was calculated for each subject in the PDP condition, for each retention interval. The non-studied scores were not collapsed over retention interval because non-studied scores from the PDP were required for each retention interval for use in the next analysis.

A 6 X 2 analysis of variance was conducted on non-studied scores as a function of test type and retention interval. There were 6 test type conditions: (1) standard implicit memory, (2) PDP, (3) blocked G/R, (4) item G/R, (5) baseline, and (6) explicit memory. The interaction was not significant, $F(5,180) = 1.30$, $MSE = .008$. Further, the effects of test type and retention interval were not significant, $F(5,180) < 1$, and $F(1,180) = 1.53$, respectively. The mean non-studied scores are presented in Table 3. The average non-studied score for all test type conditions was .25. This analysis indicates that baseline rates do not differ across the test type conditions or retention interval conditions. Consequently, estimates of priming and automatic retrieval for the test type conditions were not corrected for baseline rates.

Estimates of Automatic Retrieval

The analysis of response times suggests that priming on the speeded implicit memory task of the G/R conditions is not contaminated with intentional retrieval, and that priming on the speeded implicit memory task provides a valid index of automatic retrieval, p(A). Estimates of automatic retrieval from the standard implicit memory task and from the PDP were compared with this index of automatic retrieval from the speeded implicit memory task. With these comparisons, it can be determined whether estimates of automatic retrieval from the standard implicit memory task and from the PDP are also valid.

A 4 X 2 analysis of variance was conducted on automatic retrieval estimates as a function of test type and retention interval. There were 4 test type conditions: (1) speeded implicit memory of blocked G/R, (2) speeded implicit memory of item G/R, (3) standard implicit memory, and (4) PDP. For subjects in the standard implicit memory condition, automatic retrieval was estimated by the proportion of stems completed with studied words on the standard implicit memory task. Similarly, for subjects in the G/R conditions, automatic retrieval was estimated by the proportion of stems completed with studied words on the speeded implicit memory task. For subjects in the PDP condition, automatic retrieval was estimated using Equation 10 based on their inclusion and exclusion scores. The mean automatic retrieval estimates, p(A), are presented in Table 3.

There was a significant interaction of test type and retention interval, and significant main effects of both test type and retention interval, $F(3,120) = 9.41$, $MSE = .014$, $F(3,120) = 16.19$, and $F(1,120) = 11.83$, respectively. To aid interpretation of the interaction, an analysis of simple main effects was conducted. The simple main effect of test type at the immediate retention interval was significant, $F(3,60) = 19.98$, $MSE = .017$, whereas the simple main effect of test type at the 7-day retention interval was not significant, $F(3,60) < 1$, $MSE = .010$. To aid interpretation of the simple main effect at the immediate retention interval, linear contrasts were conducted.

For the immediate retention interval, linear contrasts comparing the blocked G/R condition with the item G/R condition and comparing the average of the G/R conditions with the standard implicit memory condition were not significant, $F(1,60) = 1.80$, and $F(1,60) < 1$, respectively. However, a linear contrast comparing the PDP condition with the average of the G/R conditions and the baseline condition was significant, $F(1,60) = 58.04$.

In sum, these results indicate that for the 7-day retention interval, automatic retrieval estimates from both the standard implicit memory and PDP conditions are similar to automatic retrieval estimates from the G/R conditions. However, for the immediate retention interval, although the automatic retrieval estimate from the standard implicit memory condition is similar to the estimates from the G/R conditions, the estimate from the PDP condition is less than the estimates from the G/R conditions.

Because the reaction time analyses indicated that priming from the speeded implicit memory tasks for the G/R conditions provides a valid index of automatic retrieval, these results indicate that, for the 7-day retention interval, estimates of automatic retrieval from both the standard implicit memory and PDP conditions are valid. This result is not surprising because recollection is low for the 7-day retention interval (.17). When recollection is low, contamination of the standard implicit memory test with intentional retrieval should be minimal. Similarly, when recollection is low, even if automatic retrieval and recollection are positively correlated, underestimation by the PDP should be minimal. However, for the immediate retention interval, these results indicate that the automatic retrieval estimate from the standard implicit memory test is valid, but that the estimate from the PDP underestimates automatic retrieval (PDP estimate = .21; blocked G/R estimate = .47; item G/R estimate = .54).

In sum, the standard implicit memory condition provides a valid index of automatic retrieval at both retention intervals. In contrast, the PDP underestimates automatic retrieval when recollection is high (immediate retention interval), but not when recollection is low (7-day retention interval). This pattern of underestimation by the PDP is predicted by the hypothesis that automatic retrieval and recollection are positively correlated, suggesting that either the independence or recollection assumption underlying the PDP are violated, or that both are violated.

Finally, simple main effects of retention interval for the standard implicit memory and PDP condition were conducted to determine whether these results were consistent with previous studies. A simple main effect of retention interval for the standard implicit memory condition was significant, $F(1,30) = 13.48$, $MSE = .010$. Priming decreased from an immediate (.49) to a 7-day retention interval (.36), consistent with results from previous studies using implicit memory tasks (e.g., Roediger & Blaxton, 1987; Roediger et al., 1992; Sloman et al., 1988). A simple main effect of retention interval for the PDP condition was also significant, $F(1,30) = 5.74$, $MSE = .019$. Automatic retrieval estimates increased from an immediate (.21) to a 7-day retention interval (.33), consistent with the findings of Stolz and Merikle (1995).

Conditional Automatic Retrieval Given No Recollection

Using equation 9, estimates of conditional automatic retrieval given no recollection, $p(A|\bar{R})$, were calculated for each subject in the PDP condition, based on their inclusion and exclusion scores. For each subject in the G/R conditions, estimates of $p(A|\bar{R})$ were calculated using Equation 18, based on their responses on the speeded implicit task and recollection test. Table 3 presents the means for estimates of $p(A|\bar{R})$.

A 3 X 2 analysis of variance was conducted on $p(A|\bar{R})$ as a function of test type and retention interval. The three test type conditions were: (1) PDP, (2) blocked G/R, and (3) item G/R. There was no interaction, $F(2,90) = 2.22$, $MSE = .020$, and no effect of test type, $F(2,90) < 1$, indicating that $p(A|\bar{R})$ for the G/R conditions did not differ from each other, or from $p(A|\bar{R})$ for the PDP condition. Finally, there was an effect of retention interval, $F(1,90) = 5.04$, indicating that the average $p(A|\bar{R})$ for the PDP and G/R conditions was greater for the 7-day than the immediate retention interval (immediate = .23, 7-day = .30). This increase in $p(A|\bar{R})$ over time is consistent with results from Stolz and Merikle (1995).

In sum, for the immediate retention interval, the PDP accurately estimated automatic retrieval conditionalized on no recollection, $p(A|\bar{R})$, but underestimated unconditional automatic retrieval, p(A). This pattern of results is predicted by the hypothesis that automatic retrieval and recollection are positively correlated. The correlation hypothesis predicts that the PDP should accurately estimate $p(A|\bar{R})$, but rejects the assumption that $p(A|\bar{R}) = p(A)$, and predicts instead that $p(A|\bar{R}) < p(A)$, which was precisely the pattern of results found.

Recollection

Using equation 5, estimates of recollection, p(R), were calculated for each subject in the PDP condition, based on their inclusion and exclusion scores. Table 2 presents the mean inclusion and exclusion scores. For each subject in the G/R conditions, estimates of recollection were calculated using Equation 5, based on their responses on the speeded implicit task and recollection test. Table 3 presents the mean estimates of recollection, p(R).

A 3 X 2 analysis of variance was conducted on recollection as a function of test type and retention interval. The three test type conditions were: (1) PDP, (2) blocked G/R, and (3) item G/R. There was no interaction, $F(2,90) < 1$, $MSE = .025$, and no effect of test type, $F(2,90) = 1.49$, indicating that recollection in the G/R conditions did not differ from each other, or from recollection in the PDP condition. Finally, there was an effect of retention interval, $F(1,90) = 104.15$, indicating that average recollection in the PDP and G/R conditions was greater in the immediate than in the 7-day retention interval condition (immediate = .50, 7-day = .17).

Before proceeding, recall that for the PDP condition, automatic retrieval and recollection are assessed at the same time. However, for a study word in the blocked G/R condition, automatic retrieval is assessed during the speeded implicit memory task, and recollection is assessed later during the recollection task. It is reasonable to assume that this separation over time might affect the retrieval process for the blocked G/R condition. Therefore, the item G/R condition was included, which assessed automatic retrieval and recollection for a study word at the same time, though still with separate memory tasks. The finding that estimates of recollection and automatic retrieval conditionalized on no recollection did not differ for the PDP, item G/R, and blocked G/R conditions indicates that the separation over time of the assessments of automatic retrieval and recollection for the blocked G/R condition did not significantly alter the retrieval process relative to the item G/R and PDP conditions.

Independence of Automatic Retrieval and Recollection

In sum, both estimates of conditional automatic retrieval given no recollection, $p(A|\bar{R})$, and estimates of recollection, $p(R)$, were similar for the PDP and G/R conditions, suggesting that the retrieval processes may be similar for the PDP and G/R conditions, and that $p(A|R)$ derived from the G/R conditions may also reflect $p(A|R)$ for the PDP condition.

In contrast to the assumption that $p(A|R) = p(A|\bar{R})$ that underlies Jacoby's (1991) direct retrieval model, both the correlation and involuntary conscious memory hypotheses suggest that automatic retrieval and recollection are positively correlated such that $p(A|R) > p(A|\bar{R})$. For each subject in the G/R conditions, these conditional probabilities of automatic retrieval were estimated using Equations 18 and 19. Table 3 presents the means for these conditional probabilities of automatic retrieval.

A 2 X 2 X 2 analysis of variance was conducted on conditional automatic retrieval as a function of conditional probability, test type, and retention interval. There were two conditional probability conditions: (1) $p(A|R)$, and (2) $p(A|\bar{R})$. There were two test type conditions: (1) blocked G/R, and (2) item G/R. None of the interactions were significant (conditional probability by test type by retention interval, $F(1,60) = 2.96$, $MSE = .042$; conditional probability by test type, $F(1,60) = 2.52$; conditional probability by retention interval, $F(1,60) = 1.06$; test type by retention interval, $F(1,60) < 1$, $MSE = .034$). The only significant effect was conditional probability, $F(1,60) = 199.88$, indicating that conditional automatic retrieval given recollection, $p(A|R)$, was significantly greater than conditional automatic retrieval given no recollection, $p(A|\bar{R})$, [$p(A|R) = .78$; $p(A|\bar{R}) = .26$].

These results indicate that automatic retrieval and recollection are positively correlated for the G/R conditions. Because memory estimates [$p(R)$ and $p(A|\bar{R})$] from the G/R and PDP conditions were similar, there is evidence that the retrieval processes for the G/R and PDP conditions are similar. Therefore, these results suggest the possibility that automatic retrieval and recollection are also positively correlated for the PDP condition. These results converge with the analysis of automatic retrieval estimates which indicated that the PDP underestimates automatic retrieval for the immediate retention interval when recollection was high. This pattern of automatic retrieval underestimation is expected if automatic retrieval and recollection are positively correlated (Curran & Hintzman, 1995).

Discussion

Using the PDP, an increase in automatic retrieval from a short (.21) to a long (.33) retention interval was found, replicating the pattern found by Stolz and Merikle (1995). Using a standard implicit memory test, a decrease in automatic retrieval from a short (.49) to a long retention interval (.36) was found, consistent with previous studies using implicit memory tasks (e.g., Roediger & Blaxton, 1987). The purpose of the study was to explain these contrasting results.

First, evidence from response times supported the conclusion that priming on the speeded implicit memory tasks for the G/R conditions provided valid estimates of automatic retrieval. Second, estimates of automatic retrieval from the implicit memory and PDP conditions were compared with the estimates determined to be valid from the G/R conditions. It was concluded that: (1) the standard implicit memory condition provided a valid index of automatic retrieval at both retention intervals, suggesting that priming on this task was not contaminated with intentional retrieval, and (2) the PDP underestimated automatic retrieval for the immediate retention interval, when recollection was high, but not at the 7-day retention interval, when recollection was low. This pattern of underestimation by the PDP supported the conclusion that automatic retrieval and recollection were positively correlated. Third, estimates of recollection, $p(R)$, and of conditional automatic retrieval given no recollection, $p(A|\bar{R})$, were both found to be similar for the PDP and G/R conditions. It was concluded that the PDP accurately indexes automatic retrieval conditionalized on no recollection, $p(A|\bar{R})$. Finally, for the G/R conditions, estimates of automatic retrieval conditionalized on no recollection, $p(A|\bar{R})$, were compared with estimates of automatic retrieval conditionalized on recollection, $p(A|R)$. It was concluded that $p(A|R) > p(A|\bar{R})$, indicating that automatic retrieval and recollection were positively correlated. Because estimates of $p(R)$ and $p(A|\bar{R})$ were both similar for the PDP and G/R conditions, it was suggested that similar retrieval processes may have been used by subjects in the PDP and G/R conditions. If this is the case, then $p(A|R)$ derived from the G/R conditions may also reflect $p(A|R)$ for the PDP condition, again consistent with the conclusion that automatic retrieval and recollection were positively correlated for the PDP condition.

The key finding is that the PDP underestimated automatic retrieval at the immediate retention interval, when recollection was high, but not at the 7-day retention interval, when recollection was low. Based on this pattern of underestimation, it was concluded that automatic retrieval and recollection are not independent bases of responding for the inclusion and exclusion tasks. This pattern of underestimation is consistent with the conclusion that automatic retrieval and recollection are positively correlated (Curran & Hintzman, 1995).

A positive correlation of automatic retrieval and recollection is consistent with several conceptualizations of retrieval. I will describe three conceptualizations of retrieval which postulate two retrieval processes that are positively correlated. First, generate/recognize theories (Jacoby & Hollingshead, 1990) suggest that intentional retrieval or recognition is completely dependent on automatic retrieval. Second, Curran and Hintzman (1997) suggest that automatic and intentional retrieval may share some processing stages. Third, a facilitation model is described which suggests that intentional retrieval of a studied item is facilitated by automatic retrieval of the studied item.

Generate/Recognize Strategies

Several researchers have suggested that subjects may use generate/recognize retrieval strategies on some inclusion and exclusion tasks (Bodner, Masson, & Caldwell, submitted; Curran & Hintzman, 1995; Richardson-Klavehn & Gardiner, 1995; Richardson-Klavehn et al., 1994). For example, on inclusion and exclusion tasks that are cued with word stems, subjects might first automatically retrieve or generate a word for the stem, and then attempt to recognize (recollect) whether the generated word was previously studied. All studied items that are recollected are assumed to have been automatically retrieved. This necessitates that the probability that a studied item is automatically retrieved given that it is recollected is equal to one, $p(A|R) = 1$. Except for extreme cases, the probability that a studied item is automatically retrieved given that it is not recollected will be less than one, $p(A|\bar{R}) < 1$. Therefore, for generate/recognize theories, automatic retrieval and recollection are expected to be positively correlated such that $p(A|\bar{R}) < p(A) < p(A|R) = 1$. Generate/recognize theories are thus consistent with the conclusion from the present experiment that automatic retrieval and recollection are positively correlated.

This type of generate/recognize theory is consistent with a redundancy model (Joordens & Merikle, 1993). The redundancy model assumes that the probability of automatically retrieving (generating) a studied item given that it is recollected (recognized) is equal to one, $p(A|R) = 1$. By substituting this assumption into Equation 16, it is determined that the redundancy model estimates the unconditional probability that a studied word is automatically retrieved as the probability of responding with a studied word on the inclusion task, $p(A) = p(\text{Inclusion})$. Using a redundancy assumption, the estimate of automatic retrieval from the PDP is .76 for the immediate retention interval, and .51 for the 7-day retention interval. A comparison of these automatic retrieval estimates with estimates from the G/R conditions (average for immediate = .51, average for 7-day = .36) suggests that the PDP overestimates automatic retrieval at both retention intervals. However, the retention interval effect would be similar for the PDP and G/R conditions — automatic retrieval decreases over time.

Before concluding that use of the PDP with a redundancy model overestimates automatic retrieval, it should be noted that automatic retrieval is conceptualized differently for generate/recognize models than it was for the present experiment. In the present experiment, automatic retrieval was indexed as performance on an implicit memory task that was not contaminated with intentional retrieval. Generate/recognize theories would suggest that automatic retrieval should be indexed as performance on an inclusion task, which is an explicit memory task that encourages guessing. That is, generate/recognize theories assume that all studied items retrieved, whether with or without recollection, were automatically retrieved. Therefore, it is not surprising that automatic retrieval estimates using the PDP based on a redundancy model are greater than estimates of automatic retrieval from the G/R conditions. Because of the different conceptualisations of automatic retrieval, comparisons of estimates of automatic retrieval from the G/R conditions with estimates from a generate/recognize model are inappropriate. However, the conclusion from the present experiment that automatic retrieval and recollection are positively correlated is consistent with generate/recognize theories.

Shared Retrieval Processes

For automatic and intentional retrieval to be independent, they must be separate and distinct processes; they cannot share any processing stages that are affected by processing at study. Furthermore, processing at study that facilitates automatic retrieval processes cannot facilitate intentional retrieval processes. If both automatic and intentional retrieval are facilitated by processing at study, then a positive correlation of automatic and intentional retrieval would be expected, violating the independence assumption.

Curran and Hintzman (1997) suggest instead that automatic and intentional retrieval could share some processing stages. For example, they have suggested that it is plausible that automatic and intentional retrieval share a 'lexical access' stage. Any processing done at study that facilitates this common lexical access stage would be expected to facilitate both automatic and intentional retrieval, causing a positive correlation. Furthermore, even if automatic and intentional retrieval do not use the same lexical access stage, they may be expected to each have their own lexical access stage. Again, any processing done at study that facilitates lexical access would be expected to facilitate both automatic and intentional retrieval, causing a positive correlation.

Facilitated Processes

Another retrieval model that would be consistent with a positive correlation of automatic retrieval and recollection is a facilitation model. In a facilitation model, automatic and intentional retrieval would be separate but not independent processes, each producing potential solutions for the stem. Because automatic processes are generally considered to be quicker than intentional processes, the automatic retrieval process typically would produce a word quicker than the intentional retrieval process. When the automatic retrieval process generates a word before the intentional retrieval process is completed, the automatically retrieved word would be communicated or input into the intentional retrieval process. If the automatically retrieved word is the studied word, then recollection would require recognition of the automatically retrieved studied word; however, if the automatically retrieved word is not the studied word, then recollection would have to proceed to recall of the studied word. It would be assumed that recognition of an automatically retrieved studied word is easier than recall of a studied word that is not automatically retrieved. Therefore, recollection (recognition) of studied words that are automatically retrieved would be expected to be greater than recollection (recall) of studied words that are not automatically retrieved. In other words, the probability of recollection given that a studied word is automatically retrieved, $p(R|A)$, would be expected to be greater than the probability of recollection given that a studied word is not automatically retrieved, $p(R|\bar{A})$. If $p(R|A) > p(R|\bar{A})$, then automatic retrieval and recollection are positively correlated. In sum, if a facilitation retrieval model as described underlies subjects' retrieval of studied items, then a positive correlation of automatic retrieval and recollection would be expected.

The difference between the facilitation and generate/recognize models is subtle. For the facilitation model, the automatic and intentional retrieval processes operate in parallel, whereas for the generate/recognize models, the recognition process follows the automatic retrieval process. For the facilitation model, a word that is automatically retrieved is communicated or input into an intentional retrieval process. Similarly, for generate/recognize models, a word that is automatically retrieved is communicated or input into a recognition process. For both models, recollection would be facilitated by automatic retrieval of a studied item. In fact, for the generate/recognize model, recollection (based on recognition) requires automatic retrieval of the studied item. In contrast, for the facilitation model, although recollection (based on intentional retrieval) is facilitated by automatic retrieval of the studied item, recollection does not require automatic retrieval of the studied item. That is, in contrast to generate/recognize models, a facilitation model suggests that a studied item can still be recollected even if it is not automatically retrieved.

The generate/recognize, shared processing, and facilitation theories each account for a positive correlation of automatic retrieval and recollection by postulating that automatic and intentional retrieval are positively correlated. However, a positive correlation of automatic retrieval and recollection still could be explained, even if automatic and intentional retrieval are independent processes. Recall that the independence of automatic retrieval and recollection depended on both the retrieval independence assumption and the recollection assumption. Although the generate/recognize, shared processing, and facilitation theories explain the positive correlation of automatic retrieval and recollection in terms of a violation of the retrieval independence assumption, the conclusion that automatic retrieval and recollection are positively correlated could be explained in terms of a violation of the recollection assumption.

Questioning the Recollection Assumption

Richardson-Klavehn and colleagues (Richardson-Klavehn & Gardiner, 1994, 1996; Richardson-Klavehn et al., 1996) questioned the recollection assumption. They suggest that recollection is not the exclusive result of successful intentional retrieval. Rather they suggest that automatic retrieval of a studied item can result in recollection, a process they term involuntary conscious memory, but I will term automatic recollection. The existence of automatic recollection would be expected to cause a positive correlation of automatic retrieval and recollection.

Subjects should respond on the exclusion task with studied items that are automatically retrieved but not recollected (see Equation 4), but should not respond with studied items that are recollected. Furthermore, if the recollection assumption is valid, subjects should respond on the exclusion task with studied items that are automatically but not intentionally retrieved, but should not respond with studied items that are intentionally retrieved. To produce valid estimates of automatic and intentional retrieval, the exclusion task must provide a valid estimate of the probability that a studied item is automatically but not intentionally retrieved, $p(A\bar{I})$ (see Equation 4).

If a studied item is automatically recollected but not intentionally retrieved, a subject presumably would not respond with that item on the exclusion task, even though it was automatically but not intentionally retrieved. Therefore, if there is automatic recollection without intentional retrieval, subjects will respond on the exclusion task with only a subset of studied items that are automatically but not intentionally retrieved (Richardson-Klavehn & Gardiner, 1994). Consequently, performance on the exclusion task will underestimate the probability that a studied item is automatically but not intentionally retrieved, $p(\text{Exclusion}) < p(A\bar{I})$. This underestimation will result in an underestimation of both the conditional probability that a studied item is automatically retrieved given that it is not intentionally retrieved, $p(A|\bar{I})$, and the unconditional probability that a studied item is automatically retrieved, p(A) (see Equation 12), and in an overestimation of intentional retrieval, p(I) (see Equation 6). Critically, the greater the number of studied items that are automatically recollected without intentional retrieval, the greater will be the underestimation of automatic retrieval. Note that this is similar to the correlation hypothesis which predicted that as recollection increases, so will the underestimation of automatic retrieval (Curran & Hintzman, 1997). Currently, there is no way to determine unequivocally whether recollection is a product of intentional or automatic retrieval. Therefore, the existence of automatic recollection also could provide an explanation for the underestimation of automatic retrieval found in the present experiment.

Contamination with Generate/Recognize Strategies

Jacoby, Begg, and Toth (1997, p. 492) state that "our goal in using the process-dissociation procedure has been to arrange conditions that encourage direct retrieval and, thereby, meet the independence assumption....Nevertheless, generate-recognize is also a reasonable strategy for cued-recall, and its use may underlie 'artifactual dissociations' such as those reported by Curran and Hintzman (1995)." Curran and Hintzman (1995) suggest that, similar to how researchers using implicit memory tests must concern themselves with the potential for contamination from intentional retrieval, researchers using the PDP must concern themselves with the potential for contamination from generate/recognize retrieval strategies.

Jacoby and colleagues (Jacoby, in press; Toth et al., 1994) suggest that, if subjects use independent automatic and intentional retrieval processes on inclusion and exclusion tasks, then the probability of responding with baseline words should not differ for the inclusion and exclusion conditions. However, they suggest that if subjects use a generate/recognize strategy, subjects will exclude studied items on the exclusion task based on recognition rather than recollection. Jacoby (in press, p. 6) states that, "because of false recognition, words that were not earlier studied would be mistakenly excluded and, so, the base rate for the exclusion test would be lower than for the inclusion test."

This logic is questionable. If non-studied target words are automatically retrieved and falsely recognized, then subjects will retrieve another word with which to respond on the exclusion task. However, false recognition of non-studied *non-target* words would also be expected to occur. Indeed the probability of false recognition of non-studied target and non-studied non-target words should be approximately equal. If non-studied non-target words are automatically retrieved and falsely recognized, subjects will retrieve another word with which to respond on the exclusion task; this second word retrieved could be the non-studied *target* word. Therefore, false recognition of non-studied non-target words might cause an increase in the baseline rate for the exclusion task. Because false recognition of non-studied target words is expected to cause a decrease in the baseline rate for the exclusion task, and false recognition of non-studied non-target words may cause an increase in the baseline rate for the exclusion task, it is not clear that subjects' use of generate/recognize strategies will cause the exclusion baseline rate to be less than the inclusion baseline rate. In fact, Bodner et al. (Experiment 2, submitted) report that even when subjects were given generate/recognize instructions, baseline performance for inclusion and exclusion conditions did not differ. Therefore, even when inclusion and exclusion baseline rates are similar, subjects may still be using a generate/recognize strategy. They concluded that similar baseline rates cannot be used as evidence that subjects use independent automatic and intentional retrieval processes.

Furthermore, Richardson-Klavehn and Gardiner (1995) found that performance on an exclusion task was the same for subjects given generate/recognize instructions and for subjects given direct retrieval instructions. They argue that subjects used a generate/recognize strategy, even when given direct retrieval instructions. It is therefore difficult to know when subjects are using independent automatic and intentional retrieval processes, as opposed to using generate/recognize retrieval strategies on inclusion and exclusion tasks. Consequently, it may be easier to devise implicit memory tasks that minimize contamination with intentional retrieval, than it is to ensure that subjects are not using generate/recognize retrieval strategies on inclusion and exclusion tasks.

Evidence for Independence?

Jacoby et al. (1997, Table 1) present data from several experiments which show that experimental manipulations of attention and presentation duration consistently affect recollection but not automatic retrieval. They argue that the consistent finding that automatic retrieval remains invariant, whereas recollection changes, provides evidence that automatic retrieval and recollection are independent. Jacoby (in press, p. 44) states that, "process dissociations showing effects on R in combination with relative invariance of A should be consistently found only if R and A are independent."

However, invariance of automatic retrieval estimates may be expected even if automatic retrieval and recollection are positively correlated. For example, one of the studies Jacoby et al. (1997) cite is the Jacoby et al. (1993) study, which showed that a manipulation of attention at study affected recollection (full attention = .25; divided attention = .00), but had no effect on automatic retrieval (full attention = .47; divided attention = .46). If automatic retrieval and recollection are positively correlated, then underestimation of automatic retrieval should occur for the full attention condition, because recollection is .25, but not for the divided attention condition, because recollection is .00. Therefore, true automatic retrieval for the full attention condition should be higher than .47. To illustrate the point, assume that true automatic retrieval is .55 for the full attention condition, whereas true automatic retrieval for the divided attention condition is still .46. The idea that automatic retrieval is greater for a full than for a divided attention condition seems as plausible as the idea that automatic retrieval is not affected by a manipulation of attention. Working in reverse, if automatic retrieval and recollection are positively correlated, and automatic retrieval is greater for a full than for a divided attention condition, then invariance of the automatic retrieval estimate may be expected. Similarly, if it is assumed that automatic retrieval is greater for a long than for a short presentation duration, and automatic retrieval and recollection are positively correlated, then invariance of automatic retrieval estimates for a manipulation of presentation duration may not be surprising. In sum, if it is postulated that manipulations of attention and presentation duration affect true automatic retrieval, then invariance of automatic retrieval estimates may not be surprising, when automatic retrieval and recollection are positively correlated. Curran and Hintzman (1997) present several other reasons, including biased sampling of studies and weak statistical power, for questioning whether this pattern of invariance of automatic retrieval across experiments provides evidence for independence.

Implications for Interpreting other PDP and Implicit Memory Experiments

I do not suggest that the independence assumption is violated and automatic retrieval is underestimated for all PDP tasks, or that no implicit memory tests are contaminated with intentional retrieval. However, it is plausible that the independence assumption is violated and that automatic retrieval is underestimated for other PDP experiments that contain inclusion and exclusion tasks cued with stems. Generation of words from stems is a relatively easy task, and therefore may encourage generate/recognize strategies or facilitate automatic recollection causing a positive correlation of automatic retrieval and recollection. Furthermore, because generation of words from stems is a relatively easy task, implicit memory tests cued with stems may discourage contamination with intentional retrieval. Subjects may be expected to follow implicit memory instructions to respond with the first word that comes to mind, when it is easy to do so, as in a stem completion task.

Based on this argument, automatic retrieval and recollection may be positively correlated for any PDP experiments that contain inclusion and exclusion tasks cued with stems (e.g., Jacoby et al., 1993; Toth et al., 1994) and therefore should be interpreted with caution. For example, as described previously, Toth et al. (1994, Experiment 1) manipulated depth of processing at study and had subjects complete inclusion, exclusion, and implicit memory tasks cued with stems. They found that the PDP estimate of intentional retrieval for words that were semantically processed at study (.27) was greater than the estimate for words that were nonsemantically processed (.03). However, the PDP estimate of automatic retrieval for semantically processed words (.42) was not significantly different from the estimate for nonsemantically processed words (.45). Further, they found that performance on the implicit memory test was greater for semantically processed words (.51) than for nonsemantically processed words (.45). Toth et al. assumed that the PDP estimates of automatic retrieval were valid, and concluded that semantic processing of words has the same effect on automatic retrieval as nonsemantic processing of words. Because estimates from the PDP indicated that the depth of processing manipulation affected intentional retrieval but not automatic retrieval, Toth et al. concluded that the depth of processing effect found on the implicit memory test was attributable to contamination with intentional retrieval.

However, findings from the present experiment suggest that this may be a misinterpretation of their findings. That is, their assumption that the PDP estimates of automatic retrieval were valid may be incorrect. If as found in the present experiment, automatic retrieval and recollection are positively correlated, then the estimate of automatic retrieval for semantically processed words (when recollection was high) may be underestimated, whereas priming on the implicit memory test may provide a valid index of automatic retrieval. This interpretation would suggest that the depth of processing effect found on the implicit memory test was attributable to automatic retrieval, but that the PDP underestimated automatic retrieval for semantically processed words.

Conclusion

Finally, Toth and Reingold (1996, p. 56) assert that the PDP and an implicit memory test should produce the same result if "the two paradigms are measuring the same construct and the implicit test is uncontaminated by conscious uses of memory". Results from the present experiment suggest that at least one implicit memory test (stem completion) is uncontaminated by conscious uses of memory, but that the PDP and the implicit memory test are not measuring the same construct: The implicit memory task is measuring unconditional automatic retrieval, p(A), whereas the PDP is measuring automatic retrieval given no recollection, $p(A|\bar{R})$. The PDP underestimated automatic retrieval for the immediate retention interval, when recollection was high, but not for the 7-day retention interval, when recollection was low. This pattern of underestimation supported the conclusion that automatic retrieval and recollection are positively correlated. Although a positive correlation of automatic retrieval and recollection is consistent with several different conceptualizations of retrieval, it obviously is not consistent with the assumption of independence that has been used with the PDP.

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Footnotes

[1] Besides the independence assumption, [$p(A|R) = p(A|\bar{R})$], proposed by Jacoby (1991), an exclusivity assumption (Gardiner & Java, 1993), and a redundancy assumption (Joordens & Merikle, 1993) have been suggested as plausible alternatives.

The redundancy model assumes that the $p(A|R) = 1$; therefore according to Equation 16, the redundancy model assumes that the unconditional probability that a studied word is automatically retrieved, p(A), is equal to the probability of responding with a studied word on the inclusion task, (Inclusion):

$$\begin{aligned} p(A) &= p(R)*p(A|R) + p(\bar{R})*p(A|\bar{R}) \\ &= p(R)*[1] + p(\bar{R})*p(A|\bar{R}) \\ &= [p(\text{Inclusion}) - p(\text{Exclusion})] + p(\text{Exclusion}) \\ &= p(\text{Inclusion}) \end{aligned}$$

The exclusivity model assumes that the $p(A|R) = 0$; therefore according to Equation 16, the exclusivity model assumes that the unconditional probability that a studied word is automatically retrieved, p(A), is equal to the probability of responding with a studied word on the exclusion task, p(Exclusion):

$$\begin{aligned} p(A) &= p(R)*p(A|R) + p(\bar{R})*p(A|\bar{R}) \\ &= p(R)*[0] + p(\bar{R})*p(A|\bar{R}) \\ &= p(\text{Exclusion}) \end{aligned}$$

[2] The semantically cued stem completion task was chosen as the study task, because it was expected to provide, at a short retention interval, relatively high recollection and relatively high automatic priming. Relatively high recollection was expected at a short retention interval, because semantic processing at study has been found to produce relatively high recognition of studied words (e.g., Craik & Tulving, 1975; Jacoby & Dallas, 1981). Furthermore, relatively high automatic priming was expected, because subjects generate the studied word from a word stem at both study and test. According to the transfer appropriate processing approach, the more

similar the operations at test and study, the greater will be priming (Roediger, Weldon, & Challis, 1989). For example, Gardiner, Dawson, and Sutton (1989) report that on an implicit memory test in which subjects generated a word from a word fragment at test, priming was significantly greater if at study they generated words from the same (though semantically-cued) word fragment compared to simply reading the target word at study. Finally, at the long retention interval, recollection was expected to decline to a relatively low level, whereas automatic priming was expected to either remain relatively stable, or decline marginally (e.g., Tulving et al., 1982).

Table 1.
Median response times for stem completions as a function of trial, test type, and retention interval.

Retention Interval	Trial	Test Type			
		Baseline	Blocked G/R	Item G/R	Explicit Memory
Immediate	Practice Trial 1	865 (123)	829 (114)	798 (135)	850 (138)
	Practice Trial 2	877 (156)	820 (133)	799 (166)	810 (156)
	Test Trial 1	838 (132)	844 (180)	873 (218)	1387 (514)
	Test Trial 2	850 (172)	817 (245)	848 (209)	1220 (356)
7 Day	Practice Trial 1	876 (145)	817 (153)	853 (158)	811 (102)
	Practice Trial 2	868 (179)	816 (140)	886 (190)	802 (119)
	Test Trial 1	829 (174)	804 (175)	896 (190)	1280 (343)
	Test Trial 2	854 (172)	823 (189)	821 (176)	1061 (215)

Note: Standard deviations are presented in parentheses.

Table 2.
Inclusion and exclusion scores, non-studied scores, and estimates of automatic retrieval and recollection for the PDP as a function of retention interval.

Retention Interval	Inclusion	Exclusion	Automatic Retrieval	Recollection
Immediate	.64 (.13)	.09 (.07)	.21 (.16)	.55 (.13)
Non-Studied	.28 (.12)	.26 (.09)		
7 Day	.46 (.15)	.27 (.12)	.33 (.11)	.19 (.21)
Non-Studied	.29 (.11)	.25 (.11)		

Note: Standard deviations are presented in parentheses.

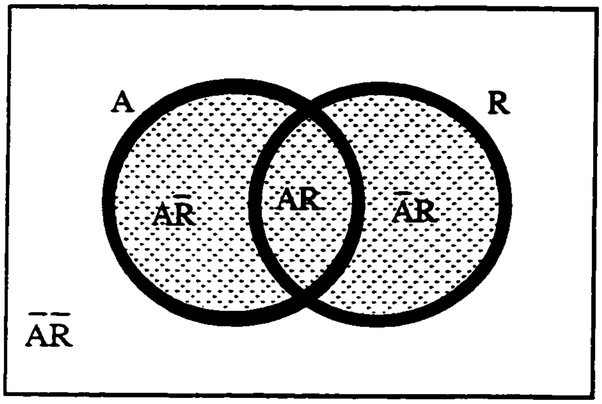
Table 3.
Estimates of unconditional recollection, unconditional and conditional automatic retrieval, and non-studied scores as a function of test type and retention interval.

Retention Interval	Memory Estimates	Test Type					
		PDP	Blocked G/R	Item G/R	Standard Implicit	Speeded Baseline	Speeded Explicit
Immediate	A	.21 (.16)	.48 (.11)	.54 (.14)	.49 (.11)		
	$A \mid \bar{R}$	.21 (.16)	.29 (.10)	.20 (.16)			
	$A \mid R$	.21 (.16)	.72 (.18)	.87 (.12)			
	R	.55 (.13)	.45 (.15)	.51 (.20)			
	Non-studied	.27 (.06)*	.24 (.07)	.23 (.10)	.28 (.12)	.26 (.07)	.27 (.09)
7 Day	A	.33 (.11)	.36 (.08)	.37 (.12)	.36 (.09)		
	$A \mid \bar{R}$	.33 (.11)	.27 (.10)	.30 (.18)			
	$A \mid R$	.33 (.11)	.75 (.29)	.77 (.31)			
	R	.19 (.21)	.16 (.12)	.16 (.11)			
	Non-studied	.27 (.08)*	.23 (.09)	.27 (.08)	.24 (.07)	.21 (.10)	.22 (.08)

Note: Standard deviations are presented in parentheses.

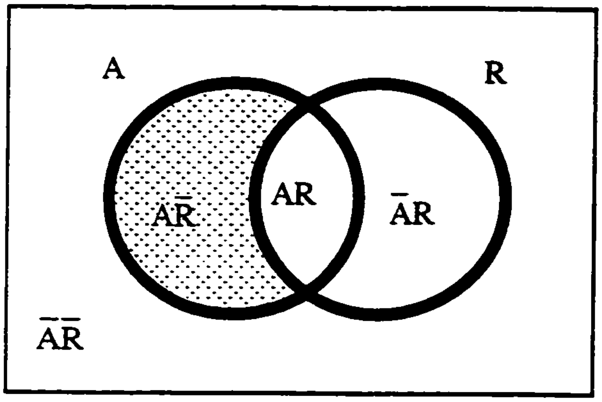
* This is the average of the non-studied scores for the inclusion and exclusion conditions.

Figure 1. Venn Diagrams for PDP Inclusion and Exclusion Conditions. 'A' represents the probability that a studied item is automatically retrieved. 'R' represents the probability that a studied item is recollected. A bar above the letter means 'not.' Thus, for example, '$A\bar{R}$' represents the probability that a studied item is automatically retrieved but not recollected.



Inclusion Condition

$$p(\text{Inclusion}) = p(A\bar{R}) + p(AR) + p(\bar{A}R)$$



Exclusion Condition

$$p(\text{Exclusion}) = p(A\bar{R})$$

Figure 2. The procedural sequence for the 6 test type conditions.

Procedure

Standard Implicit Memory

Study →	Filler →	Practice Phase	→	Test Phase	
Phase	Task	Trial 1 →	Trial 2	Implicit →	Implicit
				Trial 1	Trial 2

PDP

Study →	Filler →	Practice Phase	→		→	Post-Test Phase	
Phase	Task	Trial 1 →	Trial 2			Standard →	Standard
						PDP	PDP
						Trial 1	Trial 2

Blocked Generate/Recollect

Study →	Filler →	Practice Phase	→	Test Phase	→	Post-Test Phase	
Phase	Task	Speeded →	Speeded	Speeded →	Speeded	Recollect →	Recollect
		Trial 1	Trial 2	Implicit	Implicit	Trial 1	Trial 2
				Trial 1	Trial 2		

Item Generate/Recollect

Study →	Filler →	Practice Phase	→	Test Phase	
Phase	Task	Speeded →	Speeded	Speeded →	Speeded
		Trial 1	Trial 2	Implicit/	Implicit/
				Recollect	Recollect
				Trial 1	Trial 2

Explicit Memory

Study →	Filler →	Practice Phase	→	Test Phase	
Phase	Task	Speeded →	Speeded	Speeded →	Speeded
		Trial 1	Trial 2	Explicit	Explicit
				Trial 1	Trial 2

Baseline

Study →	Filler →	Practice Phase	→	Test Phase	
Phase	Task	Speeded →	Speeded	Speeded →	Speeded
		Trial 1	Trial 2	Baseline	Baseline
				Trial 1	Trial 2

Appendix A

Critical List 1 — Target Words, Semantic Cues, and Stem Completion Baseline Frequencies

	Target Word	Semantic Cue	Baseline Frequency (%)
Instruction List 1 Sub-list 1	sting	pain caused by a bee	13
	magnet	an object that attracts steel	20
	bread	goes in the toaster	27
	phone	a communication device	30
	cheese	milk product	17
	bullet	ammunition for a gun	20
Instruction List 1 Sub-list 2	ancient	extremely old	23
	flute	a wind musical instrument	33
	sled	a toboggan	17
	basket	woven container	20
	movie	a film	23
	south	opposite of north	27
Instruction List 2 Sub-list 1	bride	a woman about to be wed	17
	quilt	a blanket	20
	sword	weapon with a long, pointed blade	27
	garage	building to keep your car in	27
	positive	opposite of negative	17
	turtle	an animal with a shell	17
Instruction List 2 Sub-list 2	clown	circus entertainer	23
	angel	a heavenly creature	37
	chocolate	main ingredient in candy bars	17
	flower	Blossom	20
	shrink	to reduce in size	23
	glass	a material used to make windows	37

Critical List 1 — Mean Stem Completion Baseline Frequencies and Ranges

	Mean (%)	Range (%)
Critical List 1	23	13 – 37
Instruction List 1	23	13 – 33
Instruction List 2	24	17 – 37

Critical List 2 — Target Words, Semantic Cues, and Stem Completion Baseline Frequencies

	Target Word	Semantic Cue	Baseline Frequency (%)
Instruction List 1 Sub-list 1	mouth	used for talking and eating	17
	trout	type of fish	20
	burn	injury caused by a fire	27
	scream	yell loudly	30
	vertical	opposite of horizontal	13
	speak	to talk	20
Instruction List 1 Sub-list 2	balloon	helium-filled birthday decoration	23
	knife	sharp utensil for cutting	37
	hard	opposite of soft	17
	slice	to cut thinly	17
	real	opposite of fake	23
	money	currency; coins	27
Instruction List 2 Sub-list 1	brush	used to take tangles out of your hair	17
	cold	opposite of hot	20
	taste	to determine the flavour of food	27
	march	how soldiers walk	33
	reptile	a lizard	17
	sweat	to perspire	20
Instruction List 2 Sub-list 2	feather	bird plumage	23
	diamond	an extremely valuable gem	37
	cruise	trip by boat	17
	merry	happy; joyous	20
	square	a geometric shape with four sides	23
	roof	top of a house	30

Critical List 2 — Mean Stem Completion Baseline Frequencies and Ranges

	Mean (%)	Range (%)
Critical List 2	23	13 – 37
Instruction List 1	23	13 – 37
Instruction List 2	24	17 – 37

Critical List 3 — Target Words, Semantic Cues, and Stem Completion Baseline Frequencies

	Target Word	Semantic Cue	Baseline Frequency (%)
Instruction List 1 Sub-list 1	flip	to turn over	17
	steel	iron; metal	17
	crib	where a baby sleeps	27
	relish	often put on hamburgers	27
	stupid	opposite of intelligent	13
	milk	made by cows	20
Instruction List 1 Sub-list 2	dragon	a fire-breathing mythical creature	23
	polish	to shine or clean	37
	knock	rap on a door	17
	blink	to close and open your eyes rapidly	20
	stone	a small piece of rock	23
	mood	frame of mind; disposition	23
Instruction List 2 Sub-list 1	castle	a king and queen's dwelling	17
	blood	red body fluid	20
	shoe	you wear it on your foot	23
	drink	to swallow liquid	37
	rest	sleep; take a break	17
	silk	type of clothing material	20
Instruction List 2 Sub-list 2	awake	not asleep	23
	black	extremely dark	33
	pail	a bucket	17
	mustard	often put on hot dogs	20
	three	half of six	27
	string	Yarn	33

Critical List 3 — Mean Stem Completion Baseline Frequencies and Ranges

	Mean (%)	Range (%)
Critical List 3	23	13 – 37
Instruction List 1	22	13 – 37
Instruction List 2	24	17 – 37

Critical List 4 — Target Words, Semantic Cues, and Stem Completion Baseline Frequencies

	Target Word	Semantic Cue	Baseline Frequency (%)
Instruction List 1 Sub-list 1	pasta	Italian food	17
	spoon	utensil for eating cereal	20
	birch	type of tree with white bark	23
	record	to tape or copy	27
	motor	Engine	17
	horse	a farm animal	20
Instruction List 1 Sub-list 2	weep	to cry	23
	green	colour of lettuce	37
	shake	to vibrate or rattle	13
	honest	trustworthy and truthful	20
	language	human communication	23
	train	railroad vehicle	30
Instruction List 2 Sub-list 1	purple	the colour of violets	17
	think	to ponder or contemplate	20
	wallet	holds your money and identification	27
	model	small representation of an object	37
	grind	to crush or pulverise	17
	plug	keeps water in the tub	20
Instruction List 2 Sub-list 2	salt	food seasoning	23
	book	something you read	33
	curtain	window covering	17
	snake	long, tubular reptile	20
	frog	an amphibian that hops	27
	pork	flesh of a pig used as food	27

Critical List 4 — Mean Stem Completion Baseline Frequencies and Ranges

	Mean (%)	Range (%)
Critical List 4	23	13 – 37
Instruction List 1	23	13 – 37
Instruction List 2	24	17 – 37

Filler List — Target Words, and Semantic Cues

Target Word	Semantic Cue
heavy	opposite of light weight
filthy	Dirty
spring	season after winter
gloves	you wear these on your hands
clap	to applaud
dress	Gown
smart	Intelligent
brother	Sibling
fact	a true statement
package	a parcel
drunk	Intoxicated
command	to give an order
blubber	whale fat
forward	opposite of backward
couch	Sofa
grow	to increase in size
divide	to split into pieces
lunch	noontime meal
bonnet	baby's hat
rain	Precipitation
chuckle	Laugh
scared	Frightened
faint	to lose consciousness; pass out
brain	organ in your skull

Buffer Condition Study List — Target Words, and Semantic Cues

Target Word	Semantic Cue
alien	an outer space creature
Pouch	a small bag
Grass	Lawn
Cook	person who makes food
Star	galactic object
Rough	opposite of smooth
Play	opposite of work
Clean	not dirty
Bleach	to whiten
Wheel	tire on a car or bicycle
Solid	firm; rigid
Road	Highway
Corn	yellow vegetable
Fleet	a group of ships
Spin	to twist or rotate
Hint	a clue
Chair	where you sit
Prince	son of a king and queen
Vent	an opening that allows heat to enter
Slap	to hit with the palm of the hand
Ring	you wear it on your finger
Lead	a dense metal
Trip	to fall down
Person	Human

Buffer Lists — Target Words, and Semantic Cues

	Target Word	Semantic Cue
Study Buffer List	chin	part of the jaw
	wrinkle	a crease on the face
	loop	Circle
	Bent	Crooked
Non-study Buffer List	Deal	----
	Whip	----
	Swing	----
	Weak	----
Baseline Condition Study Buffer List	Adore	Love
	Camel	Humped animal
	Border	Edge
	Slow	Opposite of fast

Appendix B

Instructions for Test Type Conditions

Some of the wording of these instructions varied slightly between the immediate and 7-day retention interval conditions. The instructions that follow are written for the immediate retention interval condition, unless otherwise indicated. Minor modifications to the instructions for the 7-day retention interval condition are bracketed by a '<' and a '>' symbol.

Introduction

Thank you very much for participating in our experiment. I will remind you that you are free to leave at any time and you will not lose your credit for participating.

This experiment is part of an ongoing series of studies in which I hope to learn more about how people process information and solve problems. You will be instructed to complete a variety of straightforward tasks. <There are too many tasks to complete in one experimental session, which is why I have asked you to come back next week. So today I will ask you to complete a couple of tasks, and then I will complete the rest of the tasks next week.> Before I begin each task, I will give you instructions on how to complete the task.

Pre-Study Filler Task for 7-day Retention Interval Condition and Post-Study Filler Task for Immediate Retention Interval Condition

Your task is to solve the 'Tower of Hanoi' puzzle as quickly as possible. As you can see, there are 3 pegs on the board. All of the pieces are stacked on one peg with the largest piece at the bottom [start with four pieces]. The pieces get increasingly smaller as you move up the peg. Now you can move pieces one at a time from one peg to another peg. By moving pieces in this way, the goal is to stack these pieces in the same order on a different peg. Now I want you to do this as quickly as possible, so I will time you.

Do you understand the task? I will begin now.

[Repeat this task adding another piece each time, until approximately 7 minutes have elapsed. Each time, tell the subject that you want to see if they can solve a more difficult puzzle.]

Post-Study Filler Task for 7-day Retention Interval

Your task is again to solve the 'Tower of Hanoi' puzzle as quickly as possible. Again, I want you to do this as quickly as possible. [start with four pieces again]

Do you understand the task? I will begin now.

[Repeat this task adding another piece each time, until approximately 7 minutes have elapsed.]

Study phase Instructions

Your first <next> task is called a clue task. For each trial, you will be given the first 3 letters of a word, known as a word stem, and a clue. Your task is to respond with a target word that begins with the stem and makes sense given the clue. For example, for the stem "CRA__" and the clue "a colouring tool" the target word and correct response would be "CRAYON." There will be 52 trials on this clue task. I want to see how many of these stems you can solve, so try to do the best that you can.

If your response to a stem is correct, I will press a key on the keyboard that moves you on to the next item. If your response is wrong, then I will give you a second chance. If your response is still wrong, then I will tell you the correct answer and move you on to the next item.

Do you have any questions about this task? I will begin now.

[At the conclusion of this task, the number of items correct out of 52 is displayed on the screen.]

[At the conclusion of this task, subjects in the 7-day retention interval condition will be instructed]

That is all I want to test you on today. There are several more tasks that I will test you on next week. It is important that you come back next week, so that you will have completed all the tasks.

Instructions for stem completion practice and test trials of the standard implicit stem completion condition and for stem completion practice trials of the PDP conditions

[At the beginning of this task, subjects in the 7-day retention interval condition will be instructed]

Thank you for returning for the second session. There are several tasks I will test you on today.

[for both retention intervals]

The next task is called a stems-only task. It is similar to the clue task you completed earlier <last week.>. Again, for each trial, you will be given a three-letter word stem. However, you will not be given a clue this time. And there is no specific word that I want you to respond with. Instead, your task is to respond with the first word that comes to mind that completes the stem. I am simply interested in the frequency with which words are used in our language. So again, for each stem, there are several words that you could use, but simply respond with the first word that comes to mind. After you have given a response, I will type it into the computer; then I will go on to the next stem.

Do you have any questions? I will begin now.

PDP Instructions

You will recall that in the clue task earlier <last week>, you were instructed to complete stems from a clue. And there were target words that you produced for the stems and clues. For example, for the stem "CRA__" and the clue "a colouring tool" the target word would have been "CRAYON." The next task is called an old/new task. You will again be presented with a list of word stems. Now some of the word stems you will see on this old/new task are the same stems that you saw in the clue task. So for this task, you could complete some of the stems with the target words from the clue task.

The instructions for this task are kind of confusing, but it's important you understand, so I will go slowly. Above each stem will be either the word "OLD" or the word "NEW." The "OLD" and "NEW" words provide an instruction as to what to do with each stem. So if you see the word "OLD" above the stem, then I want you to try to complete the stem with a target word from the clue task. For example, for the stem "CRA__" and the instruction "OLD" the correct response would be the target word "CRAYON" from the clue task. However, if you can't complete the stem with a target word from the clue task, then I want you to simply respond with the first word that comes to mind. So that's if you see the "OLD" instruction.

Now the "NEW" instruction is kind of the opposite of the "OLD" instruction. If you see the word "NEW" above the stem, then I want you to try not to complete the stem with a target word from the clue task. Don't use the target word. Instead, I want you to simply respond with the first word that comes to mind that is not the target word.

After you have given a response, I will type it into the computer; then I will go on to the next word stem.

Now there are a couple of important things I want you to remember. First, only about half of the stems you will see on this task can be completed with target words from the clue task. So for about half of these stems you won't be able to remember a target word. For these stems, remember to simply respond with the first word that comes to mind. The second thing I want you to remember is to always look up at the "OLD/NEW" instruction first to see what to do with the stem.

This is a difficult and time-consuming task; but please do the best that you can. It is important that you try to be as accurate as possible in following the instructions. So I am going to help you with the first few trials just to make sure that you understand.

Do you have any questions? I will begin now.

Instructions for stem completion practice trials of explicit memory and item Generate/Recollect conditions and stem completion practice and test trials of baseline, modified PDP, and blocked Generate/Recollect conditions

[At the beginning of this task, subjects in the 7-day retention interval condition will be instructed]

Thank you for returning for the second session. There are several tasks I will test you on today.

[for both retention intervals]

The next task is called a stems-only task. It is similar to the clue task you completed earlier <last week>. Again, for each trial, you will be given a three-letter word stem. However, you will not be given a clue this time. And there is no specific word that I want you to respond with. Instead, your task is to respond with the first word that comes to mind that completes the stem. I am simply interested in the frequency with which words are used in our language. So again, for each stem, there are several words that you could use, but simply respond with the first word that comes to mind.

Now I really want that first word that pops in your head, so I am going to ask you to also respond as quickly as you can. I want you to respond very quickly and very automatically with the first word that comes to mind. The computer will record the time it takes you to respond to each stem. You should try to respond as quickly as possible after you see the stem. To help you respond quickly, a cue will appear on the screen very briefly before each stem is shown. This will tell you that the next stem is about to appear, and you should prepare to respond with a word.

After you have given a response, I will type it into the computer; then I will go on to the next stem.

There will be 4 trials of this stems-only task, each containing about 25 stems. At the end of each of the 4 trials, you will see the average time that it took you to respond to the stems in that set. You should try your best to respond faster on each set of trials than you did on the preceding set.

Do you have any questions?

I will begin now.

[Note for the explicit memory condition, go to 'Explicit memory test trial instructions' after trial 2.]

[At the end of each trial]

That is the end of trial [1,2, or 3]. Now for the next trial I want you to try to respond even faster than the previous trial(s).

Explicit Memory Test Trial Instructions

For the next two trials, I want you to do something quite different. You will recall that in the clue task earlier <last week>, you were instructed to complete stems from a clue. And there were target words that you produced for the stems and clues. For example, for the stem "CRA__" and the clue "a colouring tool" the target word would have been "CRAYON." Now some of the word stems you will see on the next two trials are the same stems that you saw in the clue task. So for the next two trials, you could complete some of the stems with the target words from the clue task.

So there are two things I want you to do. First, try to complete each stem with a target word from the clue task. And second, I want you to still respond as quickly as possible. In fact, I want you to respond even faster on the next two trials than you did on the previous two trials.

Overall, then, I want you to try to respond with target words from the clue task, and I want you to respond as quickly as possible.

After you have given a response, I will type it into the computer; then I will go on to the next word stem.

This is a difficult task; but please do the best that you can. It is important that you try to be as accurate as possible in following the instructions.

Do you have any questions? I will begin now.

Blocked Generate/Recollect Instructions

You will recall that in the clue task earlier <last week>, you were instructed to complete stems from a clue. And there were target words that you produced for the stems and clues. For example, for the stem "CRA__" and the clue "a colouring tool," the target word would have been "CRAYON." Now you just completed four trials of a stems-only task. You may or may not have noticed, but on the last two trials of the stems-only task about half of the stems were the same stems that you were given during the clue task. For example, on the clue task, if you were given the stem "CRA__" and the clue "a colouring tool," then on the stems-only task you may have been given the stem "CRA__." Now on the stems-only task, your quick response may have been, by chance, the clue task target word, "CRAYON," or your quick response may have been some other word that starts with "CRA" such as "CRAFT" or "CRAB".

The instructions for this next task are kind of confusing, but it's important you understand, so I will go slowly. You will now be presented with the same stems that you saw in the last 2 trials of the stems-only task, along with the quick responses you gave for each stem. For each trial, there are 1 or 2 questions I want you to answer. For each trial, the first question is, "Is your quick response from the stems-only task the same as a target word from the clue task?" If it is the same, say "yes"; if it's not, say "no." If you say "yes," then I will go on to the next trial. If you say "no," then I want you to answer a second question. The second question is, "Well, if your quick response is not the same as a target word, can you remember what the target word was that began with that stem?" If you can remember the clue task target word, then respond with that word. If you can't remember the target word, then just say "no."

Now there is one important thing I want you to remember. First, only about half of the stems you will see on this task can be completed with target words from the clue task. So for about half of these stems you won't be able to remember a clue task target word. So if you can't remember the target word, don't guess.

I will type your responses into the computer; then I will go on to the next trial. This is a difficult and time-consuming task; but please do the best that you can. Your responses in this final task are not timed, so you can go at your own pace. It is important that you try to be as accurate as possible in following the instructions. So I am going to help you with the first few trials just to make sure that you understand the instructions.

Do you have any questions? I will begin now.

Item Generate/Recollect Test Trial Instructions

For the next two trials I want you to do something quite different. You will recall that in the clue task earlier <last week>, you were instructed to complete stems from a clue. And there were target words that you produced for the stems and clues. For example, for the stem "CRA__" and the clue "a colouring tool" the target word would have been "CRAYON." Now some of the word stems you will see on the next two trials are the same stems that you saw in the clue task. So for the next two trials, you could complete some of the stems with the target words from the clue task.

The instructions for this next task are kind of confusing, but it's important you understand, so I will go slowly. For each trial, first I want you to do exactly what you having been doing up to now. Just respond very quickly and very automatically with the first word that comes to mind. Don't try to or try not to respond with the clue task target word. I am just interested in the first word that pops into your head. Now, your quick response may be, by chance, the clue task target word, "CRAYON," or your quick response may be some other word that starts with "CRA" such as "CRAFT" or "CRAB."

So after you have given me your quick automatic response, I want you to slow down and answer 1 or 2 questions. For each trial, the first question will be, "Is your quick response the same as a target word from the clue task?" If it is the same, say "yes"; if it's not, say "no." If you say "yes," then I will go on to the next trial. If you say "no," then I want you to answer a second question. The second question will be, "Well, if your quick response is not the same as a target word, can you remember what the target word was that began with that stem?" If you can remember the clue task target word, then respond with that word. If you can't remember the target word, then just say "no."

Now there is one important thing I want you to remember. First, only about half of the stems you will see on this task can be completed with target words from the clue task. So for about half of these stems you won't be able to remember a clue task target word. So if you can't remember the target word, don't guess. Second, people sometimes find it difficult to switch between giving a quick first response, then slowing down to search their memory for the target word, then giving a quick first response, then slowing down, etc. It's important that you really try to do this. So, first respond very quickly with the first word that pops into your head, then slow down and search your memory. I am not testing your memory with that first response, so just make your first response very quick and automatic, and then you can search your memory for your second response.

After I type your responses into the computer; I will go on to the next trial. This is a difficult and time-consuming task; but please do the best that you can. It is important that you try to be as accurate as possible in following the instructions. So I am going to help you with the first few trials just to make sure that you understand the instructions.

Do you have any questions? I will begin now.

Debriefing:

That is the end of the experiment. You may take this brief description of the research to read at your leisure. Of course, I am not able to provide you with the results of the study until all the data have been collected and analyzed. I will be posting a summary of these results during the month of December on the bulletin board where you signed up for the study. You are invited to have a look at the summary at that time. You will also be given the name and telephone number of the contact person if you have any questions.

Thank you for participating in this experiment.

IMAGE EVALUATION TEST TARGET (QA-3)

150mm

6"

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