16 Automatic Influences as Accessibility Bias in Memory and Stroop Tasks: Toward a Formal Model

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ABSTRACT Automatic processes can operate to increase the accessibility of a particular response. A series of experiments using the process dissociation procedure will be reported to show that the effects of such accessibility bias are independent of those of more algorithmic (consciously controlled) bases for responding. For example, habit originating from training in the experimental setting can produce an accessibility bias whose effects are independent of recollection. Habit serves to increase the probability of a particular response regardless of whether it opposes or acts in concert with the effects of recollection, the intended basis for responding.

The process dissociation procedure combines results from opposition (interference) and in-concert (facilitation) conditions to separate the contributions of automatic and consciously controlled processes. Use of the procedure is based on the assumption that automatic and controlled processes are *independent* bases for responding. This independence assumption can be instantiated in a model similar to a recent "counter model" advanced by Ratcliff and McKoon (1997) to provide an account of process dissociations that is more detailed, but consistent with, our original model. We have developed a variant of the counter model that accounts for effects on both speed and accuracy in Stroop tasks.

The central tenet of the "New Look" movement in perception (e.g., Bruner 1957; Greenwald 1992, along with accompanying commentaries) was that perception is strongly influenced by expectancies, values, attitudes, and needs. According to Bruner, perception involves an act of categorization, and thus reflects differences in the accessibility of categories. The notion of category accessibility has been popular in social psychology. For example, researchers have suggested that particular trait and attitude categories are more readily accessible for people who chronically process information with reference to those categories (e.g., Bargh and Pietromonaco 1982; Fazio 1986). Further, recent prior experience using a category is said to temporarily "prime" the category, making it more accessible for future use (e.g., Higgins, Rholes, and Jones 1977; Srull and Wyer 1980).

Just as perception relies on "construction" processes that reflect differences in category accessibility, memory is said to rely on "reconstruction" (e.g., Bartlett 1932). Prior knowledge in the form of "schemas" or "scripts" (Schank and Abelson 1977) is held responsible for selectivity of encoding and for the guiding of remembering. As support for this view, expertise in a domain can enhance memory performance for material from that domain. High-knowledge subjects recall substantially more from narratives relevant

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to their domain of expertise and, particularly, more essential information, than do low-knowledge subjects (e.g., Chiesi, Spilich, and Voss 1979; Chase and Simon 1973). While these results show facilitative effects of category accessibility, errors in the form of memory distortions can also result from the accessibility of prior knowledge. Because of their reliance on scripts, people sometimes report memory for "typical" actions that never actually happened in the particular event experienced (e.g., Bower, Black, and Turner 1979).

How can one take into account the biasing effects of differences in accessibility enjoyed by "typical" events when measuring perception or memory? It seems correct to refer to differences in accessibility as producing biasing effects. Recall errors produced by the accessibility of misleading prior knowledge can sometimes be eliminated by stressing accuracy (Gauld and Stephenson 1967) or by manipulating instructions to encourage literal reproduction rather than reconstruction processes (Hasher and Griffin 1978). We argue, however, that the bias effects produced by accessibility are very different from those produced by varying general willingness to respond and represented by simple criterion differences in unidimensional signal detection models (see Goldsmith and Koriat, chap. 13, this volume, for a discussion of bias effects produced by quantitative differences in the criterion for responding). Rather than producing a quantitative difference in the criterion, we argue that accessibility bias reflects the impact of a different basis for responding, whose effects can be independent of "true" memory or perception. The different bases for responding may even rely on anatomically separate memory systems (Schacter and Tulving 1994); indeed, we relate automatic, biasing effects of accessibility to memory dissociations whose discovery has generated so much interest over the last few years.

Among the most exciting developments in cognitive science has been the rediscovery of issues related to consciousness and cognitive control of performance. Dissociations between performance on direct and indirect tests supply striking examples of effects of the past in the absence of remembering. For example, although amnesiacs cannot remember the earlier presentation of a word when given a test of recognition memory or recall (a direct test), they show evidence of memory by using the word more often as a completion for a word stem or fragment (an indirect test) than they would had the word not been earlier presented (for a review, see Moscovitch, Vriezen, and Gottstein 1993). Dissociations between performance and awareness are also shown by people with normal memory (Roediger and McDermott 1993).

Automatic processes responsible for performance on indirect tests serve as a source of accessibility bias in performance on direct tests of memory. The problem of separating the contributions of automatic and controlled processes is the same as that of "correcting" for biasing effects produced by differences in accessibility. Rather than identify processes with tasks, as is typically done when explaining dissociations between direct and indirect tests, the goal of the process dissociation approach (e.g., Jacoby, Toth, and

Yonelinas 1993) has been to separate the within-task contributions of cognitively controlled and automatic forms of processing. Jacoby (e.g., 1994) used the process dissociation approach to measure recollection, a cognitively controlled basis of responding, in a way that took automatic influences of memory into account. He argued that automatic influences of memory serve as a source of "educated guessing." Because of failure to distinguish between recollection and automatic uses of memory, reliance on standard, direct tests of memory can produce serious errors in conclusions that are drawn. Here we further develop the process dissociation approach to provide a more general account of effects of accessibility bias.

First, we describe experiments done by Hay and Jacoby (1996) that used a process dissociation procedure to separate components of cued-recall performance. Results of those experiments show that making particular responses "typical" by prior training in the experimental setting produces effects of accessibility bias that are the same as those which reflect individual differences in category accessibility, and which are used to argue that memory performance reflects reconstruction. Habit and recollection sometimes act in opposition, dictating different responses, with the result that habit is responsible for memory distortions. In other situations, habit and recollection act in concert so that habit serves as a basis for correct responding rather than as a source of errors. The process dissociation approach assumes that the habit that serves as a source of educated guessing and facilitates performance when acting in concert with recollection is the same as the habit that serves as a source of errors when acting in opposition to recollection. Hay and Jacoby combined results from in-concert and opposition conditions to separate the contributions of habit and recollection to cued-recall performance.

Next, we relate the effects of habit to those of "priming," and arguing that both reflect a form of accessibility bias, we show that the effects of priming and habit in performing perceptual as well as memory tasks reflect differences in accessibility bias. Perceptual identification was among the first tasks used to show the effects of implicit memory (e.g., Jacoby and Dallas 1981). Ratcliff and McKoon (1997) have advanced a counter model to describe the biasing effect of implicit memory for a prior presentation of a word on its later perceptual identification. We reanalyze results from their experiments to show that the biasing effect of prior study is consistent with the dissociation procedure and that the dissociation revealed by this procedure can be well described by the counter model. We report a new experiment that extends our process dissociation procedure to separate the contributions of habit and perception in a perceptual identification task.

Finally, we use the process dissociation approach to analyze performance in perhaps the quintessential experimental instantiations of an accessibility bias, Stroop tasks, which have been central to theorizing about inhibition processes and interference. For example, elderly participants show greater interference in Stroop performance than do younger participants, which has been interpreted as evidence of age-related differences in inhibition. To

accurately measure any differences in cognitive control however, one needs a procedure to separate the contributions of automatic and controlled processes. Earlier applications of the process dissociation approach to performance on Stroop tasks (Lindsay and Jacoby 1994) dealt only with accuracy of responding—a notable drawback because response times have served as the standard dependent variable in most Stroop studies and theorizing. We outline a new model, in some ways similar to Ratcliff and McKoon's counter model, to account for differences in both accuracy and response times.

16.1 MEASURING COGNITIVE CONTROL: BIASING EFFECTS OF HABIT

Separating Recollection and Habit

In the last few years, a great deal of evidence has accumulated to show dissociations between conscious recollection (explicit or declarative memory) and the effects of learning (implicit or nondeclarative memory) that enable automatic bases for responding (for a review, see Squire, Knowlton, and Musen 1993). Dissociations between these two types of memory have been shown in the animal literature (e.g., Mishkin and Appenzeller 1987; Squire 1992) and with amnesiac patients (e.g., Mayes 1988; Squire 1987). The two forms of memory have been measured by performance on different tasks, and identified with different anatomical structures. For example, Knowlton, Squire, and Gluck (1994) argued that probability learning, like habit, does not require an intact hippocampus, and thus is preserved by amnesiacs. They found that amnesiacs show evidence of probability learning, but perform more poorly than people with normally functioning memory. The poor performance of amnesiacs was attributed to an inability to supplement their preserved, more automatic form of memory (procedural memory) with recollective processes (declarative memory), which depend on an intact hippocampus.

The results reported by Hay and Jacoby (1996) suggest that the form of memory measured by indirect tests and preserved in amnesiacs plays a role in normal performance on direct tests of memory. Hay and Jacoby showed that habit in the form of probability learning serves as a source of bias in cued-recall performance. To understand the rationale underlying the process dissociation procedure used in their experiments, consider their example of searching your home for the keys to your car. Suppose that the "typical" place you keep your keys is on a table near the front door of your home but that you sometimes leave your keys on the dresser in your bedroom, which is what happened on this occasion. Given a failure of recollection, you are likely to begin your search for your keys at their typical location. "Memory slips" are errors of this sort that result when habit is not successfully opposed by recollection. In contrast, when habit and recollection act in concert, habit serves as a basis for correct responding rather than as a source of

errors. As an example, finding keys in their typical location can reflect habit, rather than one's ability to recollect having placed them there. The impact of habit, both as a source of correct responding and as a source of errors, is dependent on the strength of the habit.

The first phase of Hay and Jacoby's experiment (1996) used a training procedure to create habits of a specific strength. Words were presented paired with a fragment of a related word, and subjects were to predict how these fragments would be completed. One of two possible completions for each fragment was shown and the probability of the different completions varied. In experiment 1, a biasing effect of habit was created for some pairs by presenting a particular completion on 75% of occasions during training. For example, 15 out of 20 times when the stimulus word "knee" was shown, it was paired with the response "bend" (e.g., "knee-bend"), whereas for the other 5 presentations of "knee," it was paired with "bone" (e.g., "knee-bone"). For other, unbiased pairs in the list, the two completions were presented equally often (50/50 condition) but particular completions were arbitrarily designated as typical or atypical. Training in this first phase was meant to create habits akin to those produced by regularly leaving one's keys in a particular location.

In the second phase, the memory tests were analogous to testing for where the keys were left on a particular occasion. Short lists of paired words were presented for subjects to remember. Within each list, for some pairs, the right-hand member of the pair was the response made habitual or typical in phase 1 (e.g., "knee-bend"), whereas for other pairs, the right-hand member of the pair was the response that was atypical in phase 1 (e.g., "knee-bone"). After each study list, the left-hand member of each pair was presented along with a fragment that could be completed with either the typical or atypical response (e.g., "knee-b_n_"). Participants were asked to complete the fragment by recalling the response that was paired with the stimulus word in the short list they just studied, guessing if necessary. When the studied response was atypical, effects of habit were incongruent with recollection, and erroneously completing a fragment with the response made typical by training in phase 1 corresponded to a memory slip—false recall reflecting habit. In contrast, when the studied response was the response made typical by training, habit and recollection were congruent, and responding on the basis of habit established in phase 1 would produce a correct response.

The probability of correct recall in phase 2 for responses made typical (congruent) and atypical (incongruent) by earlier training is shown in table 16.1. For incongruent pairs, the numbers in parentheses are the probabilities of falsely recalling the typical response, a memory slip. Again, the distinction between typical and atypical responses is an artificial one for pairs whose training was unbiased (50/50 condition).

The results clearly show that habit established by prior training served as a source of bias in cued-recall performance. First, note that making a

Table 16.1 Probability of Correct Recall on Congruent and Incongruent Pairs across Each Training Condition

Training Condition	Congruent	Incongruent
75/25	.82	.63 (.37)
50/50	.71	.72 (.28)

Note: Numbers in parentheses are the probabilities of mistakenly responding with the item made typical during training on trials when an atypical item was presented on the study list.

response typical by favoring it in prior training (75/25 versus 50/50) increased the probability of false recall by an amount (.37 − .28 = .09) that was approximately the same as the increase in correct recall (.82 − .71 = .11), just as would be expected if habit produced by prior training served as a source of bias. Second, looking at the probability of correct responses, performance on congruent and incongruent pairs in the 75/25 condition (.82 and .63, respectively) was symmetrical around the unbiased, 50/50 condition (.72, collapsing across the two types of pairs). Again, this is the pattern that would be expected if the manipulation of habit produced a change in bias. Because there were functionally only two completions for each fragment (e.g., "bone" and "bend"), any bias toward a particular completion produced an effect that was symmetrical, increasing correct responses on congruent pairs by an amount that is the same as the decrease in correct responses on incongruent pairs.

Estimating Automatic and Consciously Controlled Influences

For congruent pairs, participants can give the correct response either by recollecting (R) the item presented in the study list or by relying on habit (H) when recollection fails ($1 - R$). We assume that these two bases for responding act independently. Consequently, the probability of a correct response for congruent pairs, that is, the "typical" response, is $R + H(1 - R)$. In contrast, for incongruent pairs, responding with the item made typical by training is a "memory slip". If participants fail to recollect the item presented in the study list ($1 - R$), a memory slip will occur with a probability that reflects habit (H). The probability of a memory slip for incongruent pairs is $H(1 - R)$. Using these two equations, we can compute estimates of habit and recollection. Subtracting the probability of a memory slip for incongruent pairs from the probability of a correct response on congruent pairs provides an estimate of recollection: R = Correct | Congruent − Incorrect | Incongruent. Given an estimate of recollection, an estimate of habit can be computed by simple algebra, dividing the probability of a memory slip for incongruent pairs by the estimated probability of a failure in recollection: H = Incorrect | Incongruent / $(1 - R)$.

When these estimates were calculated from the data in table 16.1, it was found that the probability of recollection was approximately the same in the

75/25 and 50/50 training conditions (.45 versus .43). In contrast, the probability of giving the typical response because of habit was much higher in the 75/25 than in the 50/50 training condition (.67 versus .48). As further documented in additional experiments and discussed by Hay and Jacoby (1996), estimates of habit reflect prior training by showing probability matching. That is, the value of the parameter *H* approximates the presentation probability in training of "typical" responses. This correspondence is less impressive for the 75% typical responses because of regression toward the mean, which is commonly found in studies of probability learning.

Varying training produced a process dissociation by influencing estimated habit but leaving the probability of recollection relatively invariant. In contrast, Hay and Jacoby (1996) showed that factors traditionally associated with cognitive control produced an opposite process dissociation. For example, requiring fast responding at the time of test reduced recollection but left the contribution of habit unchanged. These dissociations provide support for the assumption that habit and recollection serve as independent bases for responding. Equivalently, habit serves as a source of bias that must be taken into account when measuring recollection.

Process Dissociation: Converging Effects of Habit and of Priming

In the experiments described above, in-concert and opposition conditions were created by manipulating congruency with prior training so as to examine effects of habit. In contrast, most experiments using the process dissociation procedure have created those conditions by manipulating instructions at the time of test, and have examined priming produced by a single prior presentation of an item (e.g., Jacoby, Toth, and Yonelinas 1993). For an inclusion test, participants are told to report remembered items (in-concert condition) whereas for an exclusion test (opposition condition), remembered items are to be withheld. The two ways of implementing the process dissociation procedure produce parallel results. Using the inclusion/exclusion procedure, we have also manipulated factors traditionally treated as important for cognitive control and found dissociations. For example, dividing attention at study reduces recollection but leaves automatic influences invariant, as do the effects of aging (for a review, see Jacoby, Jennings, and Hay 1996). Habit and priming both produce their effects by serving as a source of accessibility bias.

Our process dissociation approach has been controversial in part because of the particular procedures used to implement the approach. Hay and Jacoby (1996) describe the advantages of creating in-concert and opposition conditions by manipulating congruity with prior training rather than by manipulating instructions. For example, some critics of the inclusion/exclusion procedure claim that participants have difficulty understanding exclusion instructions (e.g., Graf and Komatsu 1994; but see also Toth, Reingold, and Jacoby 1995). The necessity for such instructions is avoided when

conditions are created by manipulating congruity with training. Different versions of the process dissociation procedure have yielded similar results, providing support of the independence assumption, which is its most controversial assumption (e.g., see Curran and Hintzman 1995, forthcoming, along with the rebuttal by Jacoby, Begg, and Shrout (1997) and Jacoby and Shrout (1997)). Jacoby, Yonelinas, and Jennings (1997) describe alternative assumptions about the relation between automatic influences of memory and recollection, and review results supporting the independence assumption.

As these results show, implicit learning and implicit memory—the type of memory preserved in amnesiacs—can bias cued-recall performance. We found that using the process dissociation procedure to separate the within-task contributions of habit and recollection, rather than probability learning as a task (e.g., Knowlton, Squire, and Gluck 1994), provides advantages over identifying processes with tasks, as has typically been done when relating different forms of memory to different anatomical structures (Hay and Jacoby 1996). Equally important, to accurately measure recollection, it is necessary to take into account differences in accessibility that reflect habit or implicit memory and that serve as a source of bias.

16.2 SEPARATING PERCEPTION AND MEMORY

Perceptual identification has been one of the most influential indirect tests used to show memory dissociations. For example, Jacoby and Dallas (1981) found that reading a word in the experimental setting enhanced its perceptual identification when the word was later briefly flashed, and that this effect on perception did not depend on recognition memory for the word. This priming effect of prior study on perception has been important for claims of the existence of a perceptual representational system (Schacter and Tulving 1994) separate from the episodic memory system held responsible for recognition memory performance.

On the other hand, Ratcliff and McKoon (1995), along with others (Humphreys, Bain, and Pike 1989), have been critical of proposals of multiple memory systems, arguing that priming should be understood in the context of existing information-processing models, rather than attributed to a separate memory system. Ratcliff and McKoon have used a variety of procedures to show that priming is produced by a bias effect (McKoon and Ratcliff 1995; Ratcliff, Allbritton, and McKoon 1997; Ratcliff and McKoon 1995, 1996, 1997; Ratcliff, McKoon, and Verwoerd 1989). Here we briefly describe recent experiments done by Ratcliff and McKoon (1997), casting the experiments in the same terminology used by Hay and Jacoby (1996), and reanalyze the results to show convergence with results from our process dissociation procedure. We do so to emphasize the similarity of their work to our own, despite the fact that Ratcliff and McKoon have been critical of the process dissociation approach (Ratcliff, Van Zandt, and McKoon 1995). We follow the reanalysis of their experiments with a brief discussion of the "counter

model" they propose to explain the biasing effects of priming in a perceptual task. The counter model can be extended to cover data that show a double dissociation when analyzed with the process dissociation procedure. Crucially, to account for double dissociations, the counter model needs to posit separate effects on two distinct parameters in the model analogous to the two separate processes postulated by the process dissociation approach.

Biased Perceptual Word Identification

Experiment 3, reported by Ratcliff and McKoon (1997), is one of a series of experiments done to show that priming reflects a bias effect. In that experiment, each of several short study lists of words was followed by a series of perceptual-identification tests. The relation between studied and tested words was varied such that for a "congruent" condition, words flashed for the perceptual identification test were the same as those which were earlier studied (e.g., studied—"died"; flashed—"died") whereas for an "incongruent" condition, studied words differed from tested words in only a few letters (e.g., studied—"lied"; flashed—"died"). The test list also contained "new" words that were dissimilar to studied words, and whose perceptual identification served as a baseline against which performance on congruent and incongruent test items was measured. Each flashed word was followed by a forced-choice test of perceptual identification (e.g., "died"/"lied"). Participants were asked to select the word that was flashed. The flash duration of tested words was varied (15, 25, 35, and 45 msec) so as to examine any interaction between biasing effects of memory and the amount of perceptual information provided by the test.

The probability of correct identification is shown in table 16.2 for each of the three types of test item at each flash duration. The numbers in parentheses for incongruent test items are the probabilities of mistakenly selecting a studied item—an error analogous to a memory slip produced by habit in the experiments by Hay and Jacoby (1996). Prior study increased both correct

Table 16.2 Probability of Correct Forced-Choice Identification on Congruent, Incongruent, and New Pairs for Each Flash Duration, with Estimated Contribution of Perception and Memory to Perceptual Identification Performance in Ratcliff and McKoon (1997), Experiment 3

Flash Duration (msec)	Congruent	Incongruent	New	Process Dissociation Estimates	
				Perception	Memory
15	.620	.444 (.556)	.544	.064	.594
25	.750	.545 (.455)	.660	.295	.645
35	.833	.678 (.322)	.756	.511	.658
45	.883	.778 (.222)	.831	.661	.655

Note: Numbers in parentheses are probabilities of mistakenly selecting the studied item on trials when a different, albeit visually similar, word was flashed.

perception for congruent test items and false perception for incongruent tests items. Identification performance for congruent and incongruent test items was strikingly symmetrical around the baseline provided by new test words: facilitative effects of prior study shown by congruent test words were nearly identical to the interfering effects shown by incongruent test words. This pattern of results would be expected if prior study produced a bias effect on performance that was independent of "true" perception. In contrast, increasing flash duration produced an increase in correct perception for congruent test words and a decrease in incorrect perception (false alarms) for incongruent words. Flash duration had its effect through an influence on perception rather than by producing a bias effect.

Estimating Contributions of Perception and Memory

Effects of memory and effects of perception act in concert for identification of congruent test words. According to the process dissociation analysis, participants can select the correct response for a congruent test word either by perception of the test item when it is flashed (P) or by relying on implicit memory produced by prior study (M) when perception fails ($1 - P$). Assuming that these two bases for responding act independently, the probability of correct identification for congruent test items is $P + M(1 - P)$. In contrast, effects of memory and effects of perception act in opposition for identification of incongruent test words. For incongruent words, if participants fail to perceive the flashed word ($1 - P$), they will mistakenly respond by selecting the earlier-studied word with a probability that reflects memory (M). That is, the probability of a false alarm for incongruent words is $M(1 - P)$. Using these equations along with results in table 16.2, we computed the estimated contributions of memory and perception for each flash duration (far right columns in table 16.2). The results clearly show a process dissociation. Increasing flash duration increased the probability of perception (P) but left the contribution of implicit memory (M) almost perfectly invariant.

If perception and implicit memory serve as independent bases for perceptual identification performance, it should be possible to produce an opposite process dissociation by manipulating a factor that selectively influences the contribution of memory, leaving the probability of perception unchanged. Results reported by Ratcliff and McKoon (1997) also show a process dissociation of this sort. In Ratcliff and McKoon's experiment 6, test words were flashed for 35 msec and the test of perceptual identification immediately followed presentation of the study list. The procedure was the same in their experiment 7, except that a delay of thirty minutes intervened between presentation of the study list and the perceptual identification test. For that test, words were flashed for either 10 or 35 msec. Results from those two experiments along with estimates of P and M are presented in table 16.3.

Results in table 16.3 show a double dissociation. Replicating results shown in table 16.2, manipulating flash duration in experiment 7 influenced P but

Table 16.3 Probability of Correct Forced-Choice Identification on Congruent, Incongruent, and New Pairs, with Estimates of Perception and Memory for Each Flash Duration in Ratcliff and McKoon 1997, Experiments 6 and 7

Duration (msec)	Congruent	Incongruent	New	Estimates	
				Perception	Memory
35[a]	.81	.67 (.33)	.74	.48	.635
10[b]	.55	.47 (.53)	.50	.02	.541
35[b]	.77	.73 (.27)	.76	.50	.540

Note: Numbers in parentheses are probabilities of mistakenly selecting the studied item on trials when a different, albeit visually similar, word was flashed.

a. Experiment 6.

b. Experiment 7.

left M unchanged. In contrast, imposing a delay between study and test would be expected to influence the contribution of implicit memory but have no effect on perception of the flashed word. Comparing across results from experiment 6 and experiment 7, the probability of perception (P) for words flashed for 35 msec was found to be the same whether the test of perceptual identification was immediate or delayed, although the contribution of implicit memory (M) was smaller for the delayed than for the immediate test.

Ratcliff-McKoon Counter Model

To account for the effects of priming on perceptual identification, Ratcliff and McKoon (1997) advanced a more sophisticated decision model than our process dissociation procedure. Indeed, there are profound differences between the two approaches. The Ratcliff-McKoon counter model provides a detailed decision model cast in a traditional information-processing framework with precise quantitative fitting of parametric data sets, whereas the process dissociation procedure estimates the relative contributions of component processes to particular tasks without providing a fully developed computational model. Our purpose here is merely to point out that dissociations revealed by the process dissociation procedure are likely to isolate the contributions of component processes that, in turn, require separate parametric treatment in more fully developed computational models. After briefly describing the counter model, we discuss the relation between parameters in the counter model and those in the process dissociation equations, arguing that the two approaches are compatible, although cast at different levels of analysis.

The counter model assumes separate decision counters for possible words serving as responses in various perceptual identification tasks (forced-choice, yes/no, and naming tasks). Over time, the decision mechanism allocates evidence, counts, or features, to these counters until a decision criterion is met and a response made. The key feature of the model used to account for

priming effects is the assumption that prior exposure causes counters to "attract" or "steal" nondiagnostic counts or features. This attractor mechanism serves to implement a bias effect. Prior exposure of a flashed word will cause the counter for that word to steal counts from other orthographically similar counters in the response set, thereby producing facilitation. In contrast, prior exposure of an orthographically similar word will cause the counter for that word to steal counts away from the counter for the flashed word, thereby producing interference.

For expository purposes, we will restrict our discussion to the counter model's treatment of forced-choice perceptual identification, such as described above. The decision model accumulates evidence until one counter obtains K criterial counts more than any other response counter. The model assumes that there are two essential types of features that serve as evidence for any counter, namely a diagnostic count, such as a count for the feature "d" when the word "died" is presented with the distractor "lied," and nondiagnostic counts, which include other nondiagnostic perceptual features ("i," "e," and "d") as well as nonperceptual "null" features. The probability that a count is accumulated into a target word's counter is $P + B(1 - P)$, where P represents the probability that a count is a diagnostic one and B is the bias parameter. The bias parameter B captures the impact of prior exposure. Without prior exposure, the value of B is set to 0.5. Prior exposure sets the parameter B to a value greater than 0.5 (0.51 in the "model fits" presented in Ratcliff and McKoon 1997).

Ratcliff and McKoon's model accommodates differing flash durations solely by varying the P parameter of the model, consistent with the notion that as the target word's flash duration increases, more perceptual features are available to provide evidence for the decision process. This aspect of the model is wholly consistent with the more macroscopic estimates derived from the process dissociation procedure. As discussed previously, the effect of increasing flash duration is to increase the estimated impact of perception (P) in the process dissociation equation, while leaving unaffected the estimated contribution of implicit memory (M) (see table 16.2).

Are there manipulations that affect the bias parameter (B) but leave the perceptual parameter (P) unaffected? The process dissociation analysis presented in table 16.3 shows that increasing the delay between initial study and perceptual identification from 0 to 30 minutes affected the estimated contribution of implicit memory (M), leaving perception (P) unaffected. Ratcliff and McKoon (1997) did not explicitly report fits of the subset of their data reproduced in table 16.3, but our simulations of their model show that variations in the P parameter cannot adequately fit this type of pattern. The baseline conditions for an unstudied item are roughly equivalent (.74 for an immediate test and .76 for a 30-minute-delayed test). If one varies P to capture the large differences between the congruent and incongruent tests across the two conditions, the model will systematically fail to fit the baseline conditions by introducing artificially large differences favoring the

immediate-test condition. In contrast, varying the bias parameter (B) from 0.504 to 0.51 (holding constant $K = 10$ and $P = 0.525$) produced an exceptionally good fit to the data. The bias parameter (B) in the counter model reflects the effect of prior exposure, and variations in this parameter are consistent with the differences revealed by process dissociation.

The careful reader will have noted the similarity between the equation used by the process dissociation approach to describe the contributions of perception and memory to perceptual identification performance and the equation used in the counter model to describe contributions of perception and bias—the "M" in the process dissociation equation for the congruent condition is replaced by a "B" in the counter model. However, the equation in the counter model refers to a microlevel mechanism, describing how, in a single unit of time, a response counter acquires a count. In contrast, the process dissociation equation refers to the macrolevel contribution of different processes. The counter model recursively applies the equation until a response is emitted, and the process dissociation procedure applies the equation once to estimate the contributions of processes on the final response. Both models are predicated on the assumption that perception and implicit memory (bias) make independent contributions to the response or the accumulation of evidence for the response.

We have done simulations to show that the two models generally agree. Just as described above, conclusions based on a counter model agree with those from the process dissociation approach over a relatively broad range of parameter values.[1] It is not goodness of fit, but rather the interpretation of parameters that is at issue. For us, Ratcliff and McKoon's "bias" is the contribution of automatic influences of memory (implicit memory), and can be manipulated in the same ways that we have used to produce process dissociations.

Biasing Effect of Habit on Perceptual Identification

Results reported by Ratcliff and McKoon (1997) show that implicit memory produced by a single prior presentation of a word can have a biasing effect on perceptual identification performance. Does habit have a similar effect? To answer this question, we did an experiment similar to those done by Hay and Jacoby (1996) but replaced the test of memory with tests of perceptual identification.

The training phase (phase 1) of our experiment was essentially the same as that of Hay and Jacoby, during which a word was paired with a fragment (e.g., "knee b_n_"), and participants guessed how the fragment would be completed. On 2/3 of the trials the pair was then shown with the fragment completed with the typical word ("knee bend") whereas for the other 1/3 of the trials, the fragment was completed with the atypical word ("knee bone").

In phase 2 of the experiment, perceptual identification was tested by briefly flashing a word and then presenting a word paired with a fragment of

Table 16.4 Probability of Correct Fragment Completion on Congruent and Incongruent Pairs along with Estimates of Perception and Habit

			Estimates	
Duration (msec)	Congruent	Incongruent	Perception	Habit
20	.60	.40 (.60)	.01	.60
40	.78	.65 (.35)	.44	.62

Notes: Numbers in parentheses are probabilities of mistakenly responding with the typical word on trials when an atypical word was flashed.

the flashed word (e.g., flashed—"bone;" tested—"knee b_n_"). Participants were instructed to complete the fragment with the word that was flashed, and, if necessary, were to guess, so that all fragments were completed. This corresponds to a forced-choice test procedure because participants almost perfectly restricted their responses to words that were presented during training in phase 1 (e.g., "bone" and "bend"). For a congruent condition, the flashed word was the word made typical by training in phase 1, whereas for an incongruent condition, the flashed word was the atypical completion in phase 1. Flashed words were preceded and followed by a visual mask, and the flash duration of the words was varied (20 or 40 msec). The short duration was selected to be so brief as to make perception near zero.

Table 16.4 shows the probability of correct perception for congruent and incongruent test words at each of the two flash durations. The numbers in parentheses for incongruent test words are the probabilities of a false alarm, that is, reporting the "typical" completion word when it was the "atypical" word that was flashed. Estimates of the contributions of perception (P) and habit (H) are shown in the rightmost columns of table 16.4. Those estimates were computed in the same way as earlier described for computing estimates of perception and implicit memory.

Results showed that the duration of the short flash was so brief that perception was near zero. The probability of correct perception for congruent test words was nearly identical to the probability of a false alarm for incongruent test words. Consequently, it can be concluded that performance at the short-flash duration serves as a relatively pure measure of the bias effect produced by training in phase 1. Because of that bias, the probability of completing a fragment with a "typical" word was above .5. The estimated probability of perception was much higher at the long-flash duration. However, increasing the flash duration left the bias effect of habit largely unchanged, producing a process dissociation. Just as found by Hay and Jacoby (1996), the probability of giving a typical word as a response on the basis of habit roughly matched the probability in training of completing fragments with typical words (.61 versus .67).

Habit increases accessibility and serves as a source of bias in perceptual tasks, just as it does in memory tasks. Results were described using the pro-

cess dissociation approach to highlight the parallel with memory results reported by Hay and Jacoby (1996), although both the memory and perception results could as well be described in the context of the counter model by saying that bias reflecting habit has its effect through the stealing or attraction of counts. An advantage of the counter model is that it can be extended to account for differences in response times as well as accuracy. In the next section, we exploit this advantage to develop a model of performance in Stroop tasks.

16.3 MEASURING COGNITIVE CONTROL IN STROOP TASKS

Results of the experiments described above showed that rather minimal training produces effects of accessibility bias in performance on perceptual tasks. We now turn to a case for which training outside the laboratory has been extensive. In particular, we use the process dissociation approach to separate the contributions of automatic and controlled processes to the performance of a Stroop task. In the classic Stroop (1935) task, participants are asked to name the color in which words are printed (for review, see MacLeod 1991). Performance on this task is influenced by automatic, word-reading processes as well as by intended, color-naming processes. Color naming is both faster and more accurate when the word is congruent with the color name (e.g., "BLUE" printed in blue ink) than when it is not (e.g., "YELLOW" printed in blue ink). The effects of congruency are measured relative to a baseline "neutral" condition (e.g., a noncolor word or nonword stimulus printed in blue ink). We suggest that word reading in a Stroop task is a form of accessibility bias that functions like the biasing effects of habit and priming.

Stroop tasks have been particularly important for theorizing about inhibitory processes. For example, it has been argued that elderly participants show larger interference effects in Stroop tasks than do younger participants, and that this is indicative of age-related decrements in inhibitory processes (e.g., Dempster 1990; Hasher and Zacks 1988). However, when defined as the difference in performance between an incongruent condition and some "neutral" condition, the assessment of inhibition is problematic. There has long been debate about what kind of neutral items should be used (see MacLeod 1991), but Lindsay and Jacoby (1994) noted a more fundamental problem. Even given a perfect neutral condition, if word reading and color naming are independent processes, the influence of word-reading processes cannot be measured by simply subtracting performance in the neutral condition from that in the congruent or incongruent condition.

Lindsay and Jacoby analyzed Stroop performance using a process dissociation procedure based on the assumption that word-reading and color-naming processes make independent contributions to performance. To do so, they used a response deadline and scored performance in terms of accuracy rather than latency of color naming. Results of their experiments revealed

process dissociations. A manipulation of color brightness influenced the parameter representing the influence of color processing (C) but left unchanged the parameter representing the influence of word processing (W) A manipulation of the proportion of congruent and incongruent items produced an opposite dissociation, influencing W while leaving C invariant. The higher the proportion of incongruent trials, the less the contribution of automatic, word-reading processes (e.g., Logan 1980; Lowe and Mitterer 1982; Tzelgov, Henik, and Leiser 1990).

In an experiment designed to explore proportion-congruent effects on both accuracy and latency of naming responses, we required participants to produce their color-naming response prior to a short deadline. The levels of accuracy in that condition were such that we were able to use a process dissociation procedure to separate the influences of automatic and controlled processes (Lindsay and Jacoby 1994). In the following subsection, we report the effects on accuracy and latency; then we describe the process dissociation procedure and show that manipulating proportion congruent selectively influenced the contribution of automatic, word-reading processes, leaving the contribution of intended, color-naming processes unchanged. The equations used to analyze Stroop performance are different, but the rationale for the process dissociation procedure is the same as described above for memory and perceptual identification tasks. We then extend the process dissociation approach to develop a new model, in some way similar to the counter model, that accounts for both speed and accuracy effects in performance of Stroop tasks.

Item-Specific, Proportion-Congruent Manipulation

In one condition, Stroop task performance was measured in terms of accuracy within a response deadline of 550 msec whereas in the other condition, performance was measured in terms of response latency without a response deadline. For both conditions, the Stroop stimuli were the words "blue," "yellow," "green," and "white," and strings of percentage signs ("%%%%" or "%%%%%"). On each trial, one of these stimuli was presented in one of the four colors in the center of a light gray computer screen. Participants were instructed to name each Stroop item into a microphone connected to a voice key.

Proportion congruency was manipulated in an item-specific way by making two binary pairs of the four colors (e.g., "blue-yellow" and "white-green"). For congruent trials, the color name matched the color of the Stroop stimulus (e.g., "BLUE" in blue letters). For incongruent trials, the word was the other member of the binary pair (e.g., "YELLOW" in blue letters). For one binary pair (e.g., "blue" and "yellow"), trials were congruent 80% of the time, whereas for the other binary pair (e.g., "white" and "green"), trials were congruent 20% of the time. The overall proportion of congruent trials was 50% at the listwide level.

Table 16.5 Empirical and Simulated Results of Item-Specific, Proportion-Congruent Experiments

Deadlined, Item-Specific, Proportion-Congruent Stroop Results

				Estimates	
Proportion Congruent	Congruent	Neutral	Incongruent	Color Naming	Word Reading
80%	.88 (.86)	.68 (.69)	.33 (.31)	.73 (.69)	.55 (.55)
20%	.79 (.78)	.70 (.69)	.48 (.50)	.70 (.69)	.31 (.28)

Response Latency, Item-Specific, Proportion-Congruent Stroop Results (msec)

Proportion Congruent	Congruent	Neutral	Incongruent
80%	597 (595)	634 (645)	747 (740)
20%	637 (622)	655 (646)	688 (690)

Note: Numbers in parentheses are the simulated results generated by the Stroop counter model.

Results (see table 16.5) show that increasing the proportion congruency for specific items in the Stroop task increased interference on incongruent trials, and increased facilitation on congruent trials. That is, the pattern of results is the same as found when the manipulation was proportion-congruent between participants (e.g., Lindsay and Jacoby 1994). However, unlike the manipulation between participants, the *item-specific*, proportion-congruent manipulation does not allow the strategic, general (listwide) inhibition of word reading to adjust to the low-proportion-congruent condition. Such a finding provides evidence that peripheral mechanisms cannot be the sole source of proportion congruency effects in the Stroop task.

If both facilitation and interference are the result of the independent influences of word-reading and color-naming processes, and a proportion-congruent manipulation affects only one of these processes, then use of process dissociation equations should reveal invariance in the estimate of the other process. The process dissociation procedure assumes that both word-reading and color-naming processes provide independent bases for responding to Stroop test items. When presented with a congruent stimulus, participants make the correct response within the response deadline based on the influence of word-reading processes (W) plus the influence of color-naming processes (C) multiplied by the complement of the influence of the word-reading processes ($1 - W$). This is to say that on congruent trials, the response is based on the influence of color-naming processes to the extent that word-reading processes do not influence the response. Because it is assumed that these two processes contribute independently, the probability that the participant will name the color of a congruent item within the response deadline is $W + C(1 - W)$. On incongruent trials, however, participants make the correct response only based on the influence of color-naming processes multiplied by the complement of the influence of word-reading processes. Correct responses on incongruent trials are based on the influence of

color-naming processes to the extent that word-reading processes do not influence the response, and can therefore be expressed as $C(1 - W)$. Using performance on congruent and incongruent trials, we can compute estimates of the contributions of color naming and word reading. Subtracting the probability of a correct response for incongruent trials from the probability of a correct response on congruent trials provides an estimate of the influence of word reading: W = Correct | Congruent − Correct | Incongruent. Given an estimate of word reading, an estimate of color naming can be computed by simple algebra, dividing the probability of a correct response for incongruent trials by the complement of the estimate of word reading: C = Correct | Incongruent/$(1 - W)$. By applying these process dissociation equations to results from the deadline condition, we can estimate the influences of word reading and color naming for both mostly congruent and mostly incongruent items (rightmost columns in table 16.5).

Increasing proportion congruency at an item-specific level increases the estimated influence of word reading (W) but does not have an effect on the estimated influence of color naming (C). These findings once again support the hypothesis that word reading and color naming serve as independent bases for responding in the Stroop task.

Counter Model for Stroop Tasks

Here we propose a counter model to account for response deadline and response time data from the Stroop task. The counter model is constructed in a manner consistent with the process dissociation analysis of the Stroop task. Specifically, we assume that two independent processes—namely, a word-reading (W) process and color-naming (C) process—provide evidence that is accumulated in response counters corresponding to possible responses in the Stroop task (e.g., "yellow," "green," "blue," etc.). As with the Ratcliff and McKoon model (1997), evidence accumulates in the counters until one counter receives K criterial counts more than any other response counter.

The modeling of response deadline and response time data, unlike that of accuracy data, requires an explicit treatment of the dynamics of processing. We assume that the evidence provided to the counters from the color-naming (C) process takes the form of a cumulative gamma function:

$$C(t) = \frac{\beta^{\alpha}}{(\alpha - 1)!} \int_0^t e^{-\beta t'} t'^{\alpha - 1}\, dt. \tag{16.1}$$

This function assumes that the color-naming process is composed of a number of component stages or processes (α), each of which is exponentially (and identically) distributed with rate (β). The gamma function simply implements the notion that evidence from the color-naming process begins to grow monotonically over processing time (t). It is important to note that nothing crucially hinges on our choice of this particular function—our simulations

show that a number of monotonically rising functions could fit the pattern of data equally well.

One could also assume that the word-reading process is similarly modeled by a cumulative gamma function. However, we believe that doing so would miss a key difference between the respective ways the two types of processes operate in the Stroop task. Unlike the color-naming process, the output of the word-reading process must be ultimately filtered or suppressed by an attentional/control mechanism. Consistent with standard interpretations of the Stroop task, we assume that the onset of a word stimulus automatically triggers word-reading operations. With respect to the decision mechanism, however, the output of the word-reading process is subsequently attenuated by a control mechanism that serves to shift attention away from the word-reading process to the color-naming process. The net effect of this control mechanism is to produce a nonmonotonic input function, in which evidence from the word-reading (W) process grows over time to some peak value and then begins to diminish.

Sperling and colleagues (Reeves and Sperling 1986; Sperling and Weichselgartner 1995; Weichselgartner and Sperling 1987) proposed that an attentional gating mechanism can be modeled by a gamma density function, and we adopt this mechanism to describe the contribution over time of the word-reading process (W):

$$W(t) = \frac{\beta^{\alpha} t^{\alpha-1} e^{-\beta t}}{(\alpha - 1)!}, \quad t \geq 0. \tag{16.2}$$

The parameters in the gating function correspond to those in the cumulative gamma function (equation 16.1). Again, as with the cumulative gamma function, nothing crucially hinges on our choice of this function.

The Stroop counter model assumes that, during each discrete interval of time (a cycle in the model), a single count from one of the evidence sources (C or W) is acquired by one of the (response) counters. The probability that a count is allocated to the target word counter is $W + C(1 - W)$ for congruent cases and $C(1 - W)$ for incongruent cases. Here, however, W and C are based on the dynamically varying input functions, rather than on static parameters, as in the original Ratcliff and McKoon (1997) model and the process dissociation fits. This decision rule serves to allocate evidence to a counter in a manner which is proportional to the relative input level of the two processes, with, however, the automatic word-reading process being favored.

Fitting both response deadline and response-time data requires the model to account for both speed and accuracy in a consistent fashion. This is a stronger test of the model than is typical in this domain because most Stroop models have only attempted to account for response times (e.g., Logan 1980; Cohen, Dunbar, and McClelland 1990). We first fit the response time (RT) data to fix temporal properties of the model, and then examined whether the model could fit the response deadline (accuracy) data by varying only one

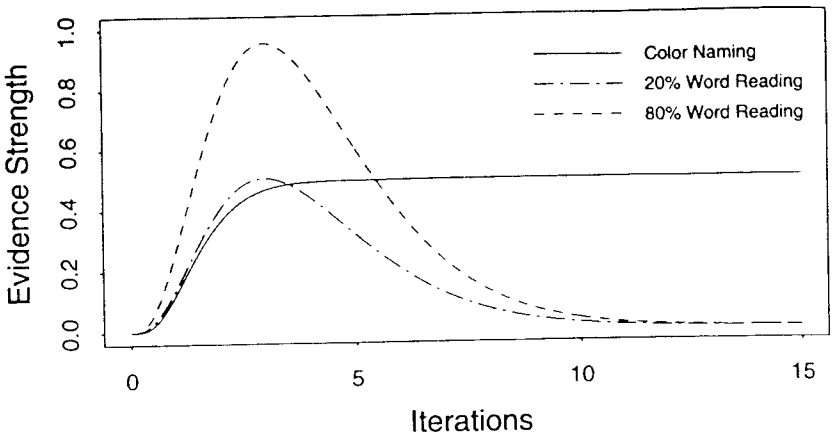

Figure 16.1 Input functions used in the simulation.

parameter (K) in the model. In the fits of the RT data, we set the criterial number of counts (K) to 21. After some exploration, we fixed the input function for the color-naming process to $\alpha = 4$ and $\beta = 2.5$, asymptotically scaling the overall function by a factor of 0.495.

The process dissociation analysis indicated that the congruency of an item affected the word-reading (W) parameter, such that when the word's name and color are most often (80%) congruent, the word-reading prices contributes more to the overall response. We parallel this treatment here by scaling the height of the word-reading (W) functions so that the function for items most often incongruent is 0.53 the value of the function for items most often congruent. We set the parameters of the gamma density function so that the rise time of the word-reading (W) functions roughly matched the rise time of the color-reading function, consistent with the notion that the two processes operate in parallel. Figure 16.1 shows the input functions that were used in the simulation.

Response time is reflected in the number of iterations (cycles) the model needs to select a correct response for both congruent and incongruent conditions. Although the mapping from iterations to (real) time need not be direct, we found that the model produced extremely good fits to the response time data with a simple linear mapping function, namely, RT $= 150 + 10$ (iterations). Table 16.5 shows the predicted and observed mean latency for a correct response from the response time variant of the task. The predicted latencies represent the average of 10,000 simulated trials per condition. Additionally, although not shown here, we have tested the model against the response time distribution collected by Spieler, Balota, and Faust (1996) and found that the model can rather precisely fit the shapes of the response time distributions for congruent, neutral, and incongruent Stroop conditions.

To fit the response deadline (accuracy) data, we lowered the criterion K to 15, consistent with the notion that subjects are likely to lower their response threshold when placed under time pressure. Based on our iteration-to-time

scaling, we set the number of iterations to 40 (corresponding to a 550 msec deadline) and then simply computed the number of correct responses that the model produced after 10,000 simulated trials per condition. Table 16.5 shows the observed and predicted accuracy values. We are impressed by the fits.

Advantages of the Stroop Counter Model

The ability to account for both accuracy and response time and the relationship between them is a benefit of our variant of the counter model for the Stroop task. Counter models also provide for the accumulation of counts not determined by either process. These "null" counts are randomly distributed into the possible responses in the response set, and provide a mechanism for "guessing" within counter models. If the threshold (K) is set to be very low and the contributions of the "microlevel" processes are also very small, "null" counts can drive the response because they will be a larger proportion of the allocated counts in the decision-making system. This is the equivalent of providing a very degraded stimulus and demanding a quick response.

The counter model shows the viability of an independence assumption for describing performance in Stroop tasks. Just as for memory and perception, the macrolevel estimates gained from the process dissociation procedure to describe performance in Stroop tasks can be coordinated with parameters in a more complete computational model, derived from the counter model. Our interest in Stroop tasks arises in part from the importance placed on such tasks as means of diagnosing deficits in cognitive control in special populations. Nearly all of the criteria suggested by MacLeod (1991) for assessing the adequacy of Stroop models rely on the assumption that the unintended effect of word-reading processes can be validly estimated as the difference between performance on incongruent items and control items. This very basic assumption requires much more careful inspection of the sort that can be gained only by contrasting it with alternative assumptions. The independence assumption reveals invariances (process dissociations) that would not otherwise be observed, and may provide a redefinition of the nature of the deficits suffered by special populations. Such a redefinition might constitute the initial step toward better diagnosis and treatment of deficits in cognitive control.

16.4 ACCESSIBILITY BIAS: TOWARD COORDINATING DIFFERENT LEVELS OF ANALYSIS

What we find exciting is the intersection of interests created by our process dissociation approach, and represented by topics considered in this chapter. Each of the separate topics has generated considerable excitement in its own domain. Discussions of individual differences in category accessibility have suggested that we construct our perceptual present (e.g., Bruner 1957) and

reconstruct our past (e.g., Bartlett 1932). Both construction and reconstruction are subject to error, leading to the dramatic claim that each of us lives in a subjectivist world of our own making. Findings of dissociations have given renewed prominence to the possibility of unconscious influences of memory and perception. Although the cognitive unconscious is very different from the psychoanalytic unconscious (Kihlstrom 1987), the role it is said to play is no less dramatic. Neurological insult can produce deficits in awareness while leaving automatic or unconscious influences preserved. Dissociations of this sort have substantially contributed to progress toward understanding the relation between brain and behavior (e.g., Knowlton, Squire, and Gluck 1994).

Although, compared to memory distortions and dissociations resulting from neurological insult, information-processing models might seem rather dull, the development of formal processing models is essential for progress on topics of more immediate interest. It is important to "correct" for accessibility bias when measuring perception or memory. To understand dissociations, it is necessary to separate the contributions of processes within a task, rather than identifying different processes with different tasks (e.g., Hay and Jacoby 1996). Important advances have been made toward developing formal decision mechanisms capable of providing a precise quantitative fit to a broad range of data (e.g., Ratcliff and McKoon 1997).

We see our process dissociation approach as being mutually supportive of, rather than antagonistic toward (cf. Ratcliff, Van Zandt, and McKoon 1995), attempts to develop detailed, information-processing models of tasks. As shown above, process dissociations identified at the macrolevel can be described at the microlevel by using a counter model (Ratcliff and McKoon 1997) as a formal model of decision processes. Although we appreciate the value of formal decision models, we have centered our work at the macrolevel to separate the contributions of automatic and consciously controlled processes. This is because a goal that is important to us is the eminently practical one of developing better means of diagnosing and treating deficits of memory and attention (e.g., Jacoby, Jennings, and Hay 1996). In pursuit of that goal, we aim for a simple model that highlights differences that are of most interest, such as age-related deficits in recollection.

Proposals of separate memory systems do not substitute for a formal processing model (McKoon and Ratcliff 1995). On the other hand, a decision model does little to help the understanding of brain-behavior relations. Our interest in dissociations causes us to side with Schacter and Cooper (1995) in questioning the explanatory power of the term *bias* as used by Ratcliff and McKoon (1995). Although the mechanism responsible for bias effects can be described within a decision model, explaining bias requires going outside such a model to specify factors that selectively influence bias and, ideally, make contact with neural data. Our macrolevel of theorizing has the advantage of revealing process dissociations that are meaningful on a priori grounds. For example, factors traditionally identified with cognitive control

selectively influence our measure of consciously controlled processing (e.g., Jacoby, Yonelinas, and Jennings 1997). We (e.g., Jacoby and Brooks 1984) prefer to account for dissociations in terms of differences in processes rather than types of memory representation, although either form of account is compatible with findings of process dissociations and could be described as constituting a proposal of separate memory or processing systems.

Describing accessibility bias effects as produced by guessing seems to deflate more dramatic claims about the importance of individual differences in category accessibility. Thus we live in a world of our own making only to the extent that true memory or perception fails. The contributions of perception and of recollection remain unchanged across large differences in accessibility bias, created by manipulating prior training. Effects of accessibility bias are more difficult to avoid in Stroop tasks, although even for those tasks, the contribution of consciously controlled processing can be adequately described as independent of that of automatic processing reflected by accessibility bias.

Does the independence assumption always hold? For example, does prior training always produce only accessibility bias, leaving "true" perception or memory unchanged? It seems almost certain that the answer to this question is "no." To claim otherwise is to deny the possibility of perceptual learning, for example, of the sort produced by a change in the features used to identify a member of a class (e.g., Biederman and Shiffrar 1987). It seems likely that the typicality of an event sometimes influences recollection as well as accessibility bias in a way that violates their independence. That the independence assumption is sometimes violated, however, does not make it less useful. Rather, findings that can be adequately described as produced by independent processes serve as a contrast against which more integral forms of processing can be defined (cf. Garner 1974).

NOTES

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1. For example, varying the bias (B) parameter in the counter model from .5 to .51 affects the memory (M) parameter of the process dissociation equation, leaving the perceptual (P) parameter unaffected. Likewise, varying the perceptual (P) parameter in the counter model from 0.0 to .05 affects the perceptual (P) parameter of the process dissociation equation, leaving the memory (M) parameter unaffected.

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