2

Modeling Distinctiveness: Implications for General Memory Theory

JAMES S. NAIRNE

The capacity to remember, to use the past in the service of the present, is a highly adaptive component of cognitive functioning. Although one need not reproduce the past, either consciously or unconsciously, in order to benefit from the service of memory, reproduction is clearly an important design feature (Anderson & Schooler, 2000; Nairne, 2005). Telephone numbers, street addresses, medication times, passwords—each needs to be recovered exactly, with the components in sequence, and inferential or reconstructive processing is unlikely to suffice.

To explain the specificity of retention, students of memory appeal often to the concept of distinctiveness, the focus of the present volume. Mnemonic distinctiveness can be defined in various ways—for example, as a property of a stored trace, a retrieval cue, or as a type of processing (see Hunt, Chapter 1 this volume; Schmidt, 1991). I define it here as the extent to which a particular cue (or set of cues) specifies a particular stored event (or target response) to the exclusion of others. Framed in this way, distinctiveness is not a fixed property of a cue, or a target trace, or even of an interaction between a given cue and a given target. It is a property of a cue in context: given a fixed set of alternatives, a measure of distinctiveness can be assigned to a particular cue with respect to a particular alternative. Change the context—for example, by changing how the cue is perceived or the range of possible responses—and the measure of distinctiveness changes as well.

To facilitate our discussion, and to add some formality to the preceding definition, I introduce a simple retrieval model below (borrowed from my feature model of immediate retention; Nairne, 1990a) and show how it helps account for some of the phenomena classically associated with the study of distinctiveness. For example, I show how the model informs us about the particulars of the von Restorff effect (Hunt, 1995;

von Restorff, 1933) and about the paradoxical effects of processing similarity and difference on episodic retrieval (Hunt & McDaniel, 1993). I then consider the role of time in the calculation of distinctiveness and contrast the retrieval model with certain extant models of temporal distinctiveness (e.g., Brown, Neath, & Chater, 2002; Neath, 1993). Finally, I end the chapter by discussing how the retrieval model forces us to reassess some widely held beliefs about memory, particularly the notion that memory is directly related to the match between an encoded cue and an encoded target.

A SIMPLE MODEL

Directed retrieval reduces ultimately to a matter of response selection. There is a vast storehouse of information in the brain; the retrieval problem is to select appropriate content based on information available in the present. When we forget an item from a memory list, we are not really forgetting the item—we are forgetting that it occurred in a particular space and time defined by the memory list; when we forget where we parked our car, we are not forgetting our car, we are forgetting the position our car occupied today as opposed to yesterday or the day before. Retrieval cues help us solve these kinds of discrimination problems. They provide us with the information we need to pick and choose from the wide variety of responses that are potentially available.

To formalize the response selection process, I adopt a simple retrieval, or choice, rule of the type often found in categorization and some memory models (e.g., Nosofsky, 1986; Nairne, 1990a, 2001). Under this formulation, an item is chosen for recall by comparing, or matching, the operative retrieval cue(s) to possible candidates in long-term memory (see also Raaijmakers & Shiffrin, 1980). The probability that any particular event, E_1, will be selected as the recall candidate depends on how well the retrieval cue, X_1, matches E_1 to the exclusion of other possible recall candidates (e.g., $E_2, E_3, \ldots, E_N$):

$$P_r\ (E_1|X_1) = \frac{s(X_1,E_1)}{\Sigma s(X_1,E_i)} \qquad (1)$$

The quantity $s(X_1,E_1)$ refers to the similarity of X_1 to E_1, which in turn varies as a function of the number of matching or mismatching features between the two terms (a distance measure). Shepard (1987) recommends relating distance (d) to similarity in the following manner:

$$s(X_1, E_1) = e^{-d(X_1,E_1)} \qquad (2)$$

This means that nearby items in psychological space (e.g., those that contain few mismatching features) will be deemed the most similar (and thereby produce the largest effects), and similarity will fall off rapidly with increasing distance.

Equations 1 and 2 are not meant to suffice as a complete model of memory. Among other things, one needs to specify how event traces are represented in memory, how probabilities translate into actual output (Nairne, 1990a; Raaijmakers & Shiffrin, 1980), and the similarity and distance measures need to be scaled appropriately as well (Nosofsky, 1986; Shepard, 1987). However, as I demonstrate below, this simple ratio model provides a nice conceptual framework for interpreting the empirical patterns of concern in the distinctiveness literature. Note that equation 1, which expresses the probability that a particular target event will be selected, doubles as our measure of distinctiveness. Distinctiveness is therefore a property of a cue, but only with respect to a particular retrieval candidate. By itself, the measure tells us nothing about whether the retrieval candidate is correct or incorrect, or good or bad from a mnemonic standpoint.

If the goal is to recover event E_1 in the presence of a particular cue X_1, then equation 1 isolates the factors that promote successful sampling. To maximize the probability of selecting E_1, it needs to be similar to the cue, X_1, and dissimilar to other possible retrieval candidates (E_2, E_3, . . . ,E_N). The numerator of equation 1 tells us that retrieval will depend importantly on the match between the retrieval cue and the target (Thomson & Tulving, 1970); the denominator quantifies cue overload, or the extent to which a cue is predictive of many things (Earhard, 1967; Watkins & Watkins, 1975). Successful recovery, put generally, will be proportional to the cue–target match and inversely proportional to the amount of cue overload. Note that because of the ratio form, neither the cue–target match nor the amount of cue overload, alone, will be sufficient to predict successful retention; successful recovery of a target will always depend on both. As I discuss later, this conclusion has a number of implications for general memory theory.

The von Restorff Effect

To illustrate how the retrieval rule works, I begin by applying it to the von Restorff effect—the so-called mother of all distinctiveness effects (Hunt & Lamb, 2001). The *von Restorff effect* (or isolation effect) refers to the memory enhancement that is found for events that differ, or deviate, from their context. In von Restorff's original experiments, participants recalled 10-item lists containing either 10 unrelated items (list 1), nine numbers and one nonsense syllable (list 2), or nine nonsense syllables and one number (list 3). The discrepant items were remembered best (e.g., the number in the list of syllables)—even better, in fact, than the unrelated items occupying similar list positions (e.g., items from list 1), or the "background" homogenous items (e.g., the syllables in list 3).

In experiments of this type, items become distinctive by virtue of their list context; that is, items are "isolated" only relative to particular backgrounds. To consider a specific case, if the number 43 was presented in each of the three von Restorff lists, we would expect its retention to be enhanced only in list 3, where it stands out from the other list items. For the effect to emerge, typically, the nonisolated (or background) items need to share some measure of similarity—that is, the detection of "difference" depends on a background of similarity (see Hunt, Chapter 1 this volume; Smith & Hunt, 2000). As I will discuss later, it is possible to reduce or eliminate the isolation advantage simply by asking people to focus their processing on how items differ from one another in a typical von Restorff list (Hunt & Lamb, 2001).

The isolation advantage also remains robust when the isolate occurs early in the list, even in the first serial position (Kelley & Nairne, 2001; Pillsbury & Rausch, 1943). This is an important finding because it suggests that the locus of the effect should be placed at retrieval. Encoding-centered accounts have been proposed over the years, and it seems reasonable to argue that isolates sometimes do capture more attentional resources (Schmidt, 1991), but encoding-centered accounts have difficulty explaining why the effect is found when the isolate occurs in the first or second serial position. At this point, no list context has been established, so there is no background of similarity against which the item can be considered unusual or especially salient. Instead, as embodied in the retrieval model, it makes more sense to assume that the isolate leads to the encoding of features that potentially help one discriminate its prior occurrence at retrieval, after all of the list items have been presented.[1]

To implement the model, it is necessary to make some assumptions about how items are represented in memory, about how similarity is calculated, and about the nature and generation of retrieval cues. Following Nairne (1990a), one can represent items as lists of features and distance derived by comparing features across each position. The number of mismatching features is summed and the total is then divided by the number of compared features. For example, suppose memory trace A is represented by a vector of five features, [C C 2 3 1], and memory trace B by a second vector, [C X 2 2 1]. A feature-by-feature comparison reveals two mismatching features—in positions 2 and 4. Dividing the number of mismatching features (2) by the number of compared features (5) gives us the distance measure (.40). This distance measure is then plugged into equation 2, yielding a similarity value of .67. (For further numerical examples, see Nairne, 1990, 2001.).

In the retrieval model, the critical similarity comparisons are between cues and viable retrieval candidates stored in long-term memory. Like most memory theorists, I assume that the immediate present is used to recover the past—that is, memories do not spontaneously appear, but rather are cue-driven (Tulving, 1983). In the feature model, which deals primarily with remembering over the short term, the operative retrieval cues are lingering records of the immediate past, which can be accessed directly (from primary memory) or recovered through context. When one is remembering over the longer term, a comparable process occurs: some version of the original encoding record is recovered via context and "interpreted" by sampling from a candidate set of possible responses. Equation 2 specifies how the recovery process proceeds: the record is compared to each possible item in the candidate set and, based on the relative similarity values, a candidate is selected for recall (see Nairne, 2001, 2002a).

A Numerical Example

Table 2.1 shows similarity and sampling probabilities for some hypothetical three-item lists. Encoded list items are represented by trace vectors of five features (e.g., a sequence of letters and digits). The first list, labeled "Control," is meant to contain three unrelated items, although, importantly, some measure of similarity is assumed (e.g., overlapping contextual features). The cue, shown to the left, is an intact version of the second list item; under normal conditions, this cue would presumably be a blurry or degraded record of the encoding, but it is presented intact here for the sake of simplicity. The last two columns show the similarity and sampling calculations based on the comparisons between this cue and each of the three list traces. Correct recall, given this cue, occurs when the second list item is sampled and successfully recovered (see Nairne, 1990a, for details).

The second list, labeled "Isolate," instantiates the isolation manipulation: A new nonoverlapping feature, *X*, is represented in the trace for item 2, replacing one of the shared contextual features (we might assume, for example, that the second list item was presented in a unique color or voice). In all other respects, items remain the same. Note that the similarity value between the cue and its long-term memory representation remains the same, 1.0, but the probability of sampling that target increases. This is the isola-

TABLE 2.1 Similarity Values and Sampling Probabilities Generated by the Retrieval Model for a Hypothetical Three-Item List

	Cue	*Traces*	*Similarity*	*Samp. Prob.*
Control	[C C 2 3 1]	[C C 1 2 3]	.55	.26
		[C C 2 3 1]	1.0	.48
		[C C 3 1 2]	.55	.26
Isolate	[C X 2 3 1]	[C C 1 2 3]	.45	.24
		[C X 2 3 1]	1.0	.53
		[C C 3 1 2]	.45	.24
Iso/Sim	[C C 2 3 1]	[B B B B 3]	.37	.21
		[C C 2 3 1]	1.0	.58
		[B B B B 2]	.37	.21

Note: All of the calculations are based on a cue vector representing the second item on the list. Sampling probabilties may not add to one because of rounding.

tion effect, and it is caused here by a reduction in cue overload: the correct target is more likely to be sampled because the cue is now less similar to other candidates. The addition of feature *X*, which is unique to the encoding of the second list item in this list context, reduces the number of matching features between the cue and the target's competitors.

The third list, labeled "Iso/Sim," shows what happens when the control item from the first list is presented against a background of highly similar items. This is the same target representation and cue as in the first list, and the cue–target match remains perfect, but the probability of correctly sampling the target increases substantially. Once again, what determines performance is the overlap between the features of the target item and those of the background items. As the similarity among the background items increases, their match with the operative retrieval cue decreases. Note, however, that it is not background similarity per se that mediates performance; what matters is the overlap between the cue and the nontarget competitors. If the similarity of the background items increases, but in a way that also increases their match with the retrieval cue, then performance would suffer rather than improve.

Of course, recovery of the isolated item in the model also depends on how well the cue matches the relevant target. The cue–target match is held constant in Table 2.1, but it easy to imagine isolation improving the functional cue–target match. For example, by definition an isolated item contains features that are unusual in that list context; consequently, those features, once encoded, are probably less susceptible to interference (i.e., overwriting) from subsequently presented items. This should help guarantee an intact cue at retrieval, one that better matches its representation in long-term memory. Moreover, when the isolated item occurs after the list context has been established, its appearance is surprising, which in turn could enrich the overall encoding (or hurt encoding in some circumstances—see Schmidt, Chapter 3 this volume). Richer or more elaborate encodings tend to be matched better by relevant retrieval cues and more protected from interference. In any given situation, it will be difficult to disentangle the relative contributions of the cue–target match and changes in the amount of cue overload; the presence or absence of unusual features is likely to affect both.

Background Recall

It is also of interest to consider how the presence of an isolated item affects recall of the nonisolated (background) items in the list. In principle, one can conceive of the isolate acting in several ways: enhancing recall of the isolate itself, reducing memory for the background items, or leading to both outcomes. The literature is somewhat equivocal in regard to background recall; sometimes the presence of an isolate hurts the retention of the other list items (e.g., Schmidt, 2002; Schulz, 1971), sometimes recall of those items improves (Farrell & Lewandowsky, 2003), and often there is no effect (e.g., Kelley & Nairne, 2001).

Theoretically, it is easy to justify any of these outcomes. From an organizational perspective, some theorists have argued that the isolate promotes the formation of two list-based categories, one containing the isolated item and a second category comprising the background items (Bruce & Gaines, 1976; Fabiani & Donchin, 1995). Because it is easier to recall items from smaller categories, better memory is expected for both the isolate and the background items. Alternatively, if the isolate captures more attentional resources, or is more likely to be rehearsed, then recall of the background items should suffer because they receive a smaller proportion of the allocated resources. One could argue as well that isolated items, because of their superior mnemonic value, will tend to be recalled early during output, rendering the remaining items subject to more output interference (e.g., Cunningham, Marmie, & Healy, 1998; Schmidt, 1985).

The retrieval model makes no explicit assumptions about encoding, organizational processing, or selective rehearsal; it merely assumes that the recall of an item (isolate or background) will depend on the cue, its match to the relevant target, and the composition of the competitor set. Table 2.2 shows the similarity and sampling values for a background item in our three hypothetical lists. In this case, the cue is for the first list item instead of the isolate, and the correct response is to sample the first of the three list vectors. (Identical values hold for the third item.) Note that the sampling probabilities for this background item change across the three conditions.

Of initial interest is the comparison between lists with and without an isolate. The probability of correctly sampling the first list item in the Control condition is .48 compared to .50 in the Isolate condition. This slight increase, which is predicted by a grouping or organizational account, is caused here by a net decrease in the amount of cue overload (the overall

TABLE 2.2 Similarity Values and Sampling Probabilities for the Background Items in a Hypothetical Three-Item List

	Cue	*Traces*	*Similarity*	*Samp. Prob.*
Control	[C C 1 2 3]	[C C 1 2 3]	1.0	.48
		[C C 2 3 1]	.55	.26
		[C C 3 1 2]	.55	.26
Isolate	[C C 1 2 3]	[C C 1 2 3]	1.0	.50
		[C X 2 3 1]	.45	.23
		[C C 3 1 2]	.55	.28
Iso/Sim	[B B B B 3]	[B B B B 3]	1.0	.46
		[C C 2 3 1]	.37	.17
		[B B B B 2]	.82	.37

Note: All of the calculations are based on a cue vector representing the first item on the list. Sampling probabilities may not add to one because of rounding.

value of the denominator in equation 1 goes down). Because there are fewer overlapping features between the isolate and everything else, the isolate is less likely to be sampled when cued by traces left by any of the other list items. Interestingly, the presence of an isolate actually increases the distinctiveness of the remaining items on the list. The effect is small because the decrease in the denominator is caused only by the comparison between the cue and the isolate; with longer lists, this contribution is less important—it is proportionally smaller—which may help explain why a null effect of the isolate on background recall is often reported.

The same reasoning applies to the third condition, Iso/Sim, although background recall is low relative to the other two conditions. Cues for the background items are less distinctive in this condition because the members of the competitor set (with the exception of the isolate) share lots of features. Despite the low sampling probability, however, background performance is not actually hurt by the presence of the isolated item; in fact, for the same reasons discussed in the preceding paragraph, having an isolate in the list improves the sampling probabilities for background items, at least relative to a list containing all similar items. From the model's perspective, any manipulation that decreases the overlap among traces will increase the likelihood of correct cue–target sampling (assuming the cue–target match remains constant). Consequently, whether background items will show a benefit, no effect, or a loss will depend on the control condition and on other factors such as the length of the lists employed.

Processing Effects

As noted, in its simplest form the retrieval model makes no assumptions about encoding or processing. The isolation effect, as well as background recall, is determined solely by the state of cues, targets, and competitors at the point of recall. However, any encoding manipulation that affects trace composition is likely to influence performance. As discussed earlier, when an isolate occurs late in a list, its surprise value could easily lead to additional processing (or more rehearsal), which in turn could produce a more elaborate memory trace. Moreover, any orienting task that causes participants to focus on common or unique features across to-be-remembered items should have significant effects on performance as well.

In one relevant study, Hunt and Lamb (2001) examined how various orienting tasks affect the isolation advantage. Participants were given lists containing either 10 related items (e.g., a list of vegetables) or 9 related items and 1 item from a different category (e.g., a tool). The standard isolation advantage was produced across the lists—that is, the tool in the list of vegetables was remembered best. Of main interest, however, were several orienting tasks that induced participants to compare item characteristics during presentation. In one condition, participants were asked to state how each item differed from the one immediately preceding it in the list;

in another condition, judgments of similarity were required. Once again, these judgments were made on lists either containing an isolate or not.

Two major findings emerged. First, when participants were asked to focus on item differences, the isolation effect was eliminated; second, when the orienting task was similarity-based, a robust isolation effect occurred. If we assume that the "difference-based" orienting task created list traces with little or no feature overlap, then the results follow nicely from the retrieval model. If traces already contain few, if any, matching features, then inserting an isolate—that is, an item with little or no matching features—should not enhance retention compared to a control. On the other hand, if the orienting task substantially increases the amount of feature overlap, by focusing attention on item similarities, then the isolate should be remembered especially well. It is interesting to note that recall of the background items followed the pattern predicted by the model as well. Difference processing led to a significant increase in background recall compared to the condition requiring similarity processing. Again, difference processing reduces the amount of feature overlap, and therefore the amount of cue overload, for both isolates and background items.

Other empirical patterns in the isolation-effect literature can be explained by reasoning of this sort. For example, it has been reported that the isolation effect is sometimes reduced or eliminated when participants report using elaborative rehearsal strategies during study (see Fabiani & Donchin, 1995). To the extent that elaborative processing leads to richer traces, ones that contain unique individual item information, then the isolation advantage should be reduced for the reasons discussed above. However, the predicted pattern will depend on the type of elaborative processing engaged. If participants relate items together, such as linking them into a cohesive story, then a very different pattern might well emerge. If the net result is an increase in feature overlap, because the processing emphasis has been placed on similarity rather than difference, the isolation advantage could increase.

THE PARADOX OF SIMILARITY AND DIFFERENCE

Our discussion up to this point has centered on the importance of difference. For a given retrieval cue, sampling probabilities are inversely proportional to the amount of cue overload; consequently, manipulations that reduce feature overlap will increase the chances of correct target sampling. However, analysts of memory have known for decades that memory often benefits from the processing of similarities as well. For example, items from categorized lists are usually recalled better than items from unrelated lists (Tulving & Pearlstone, 1966); for unrelated word lists, relational processing, or the processing of commonalities among list items, can benefit recall substantially (e.g., Hunt & Einstein, 1981).

This situation sets up a fundamental enigma or paradox: How can the processing of similarity and difference both benefit retention? From the standpoint of the retrieval model, and the notion of distinctiveness in general, similarity is anathema because it increases cue overload. However, this situation holds only with respect to a particular cue and a fixed set of possible retrieval candidates. Distinctiveness is a property of a cue in context—it merely specifies the likelihood of sampling a target given a specific cue. Left unspecified in this analysis are the variables that determine cue availability and the final composition of the target competitor set. As discussed below, it is here that organizational processing, or the processing of similarities, is apt to leave a positive mark on performance (also see Burns, Chapter 6 this volume).

The virtues of distinctiveness will depend as well on the type of retention test employed. Consider free recall, in which the goal is to recall all of the items on a just-presented list. What is the advantage of using a distinctive cue—one that specifies a single item—as opposed to an overloaded cue that is associated to a variety of items on the list? From a mnemonic standpoint, the goal is to sample any item as long as the item comes from the relevant memory list. Overloaded cues actually seem beneficial from this perspective because they promote the sampling of many list items. Of course, the situation is quite different in serial recall, which requires one to recall list items in their exact positions of original occurrence. If the cue for the second list item leads to the sampling of the third item, the response will be incorrect. Not surprisingly, similarity typically has strong negative effects on serial recall performance.

The Benefits of Relational Processing

To unravel the enigma, we need to focus more closely on the processing consequences of relational and item-based processing. In relational processing, typically participants are asked to process commonalities among to-be-remembered items, such as sorting the items into categories (Hunt & Einstein, 1981). Noting commonalities is likely to increase the amount of feature overlap across encoded traces because common features are encoded, but it can produce a very salient retrieval cue as well: participants know that the to-be-remembered items come from a particular category. Relational processing, as a result, effectively reduces the size of the long-term memory search set, increasing the probability of correct item sampling (see Burns, Chapter 6 this volume; Hunt & McDaniel, 1993; Neath, 1993).

A decade or so ago, my laboratory conduced a number of experiments to illustrate the paradoxical effects of similarity on memory (Nairne, 1990b; Nairne & Neumann, 1993). Each of these experiments tested memory for order: List items had to be placed in their exact within-list positions of occurrence at the point of test. As mentioned above, similarity usually has a strong negative effect on order retention, presumably because any given list cue tends to match lots of items from the list (e.g., the phonological similarity effect). In our experiments, however, rather than testing memory immediately following each list, researchers assessed order retention at the end of the session, after a number of lists had been presented. There were two main conditions: one in which lists were drawn from unique categories (e.g., birds, furniture) and one which contained lists of unrelated words. The surprising finding was that the categorized lists were ordered better than lists containing unrelated items. In this case, similarity helped order memory despite the fact that the within-list traces presumably contained more overlapping features than those from unrelated lists.

The unique feature of our experiments, of course, was the fact that testing occurred after the presentation of multiple lists. Compared to the normal case, in which testing occurs immediately following each list, participants faced a more difficult discrimination problem: they needed to locate not only the item's within-list position in memory but also the list representation in which the item occurred (e.g., it was the second item in the third list). With categorized lists, it should be difficult to recover an item's correct within-list position because the items share semantic features and are easily confused; however, it should be easy to identify the correct list representation because all members of a particular category come from the same list (e.g., if it is a robin, it must come from the bird list). With unrelated lists, the opposite is the case: it should be relatively easy to determine within-list position because the items are unrelated, but difficult to assess the correct list representation (there is no salient category cue to identify list membership). The net effect of similarity, therefore, will depend on a trade-off between ease of access along the list and within-list dimensions (also see Hunt, Chapter 1 this volume).

For example, suppose the probability of accessing an item's correct within-list position from memory is .30 when the list items share features and .50 when the items are distinct. If the list representation is easily available, as in the typical immediate memory context, similarity should impair performance. Further assume that when multiple lists have been presented, the probability of accessing the correct list representation in memory is .80 when the lists are categorized but only .40 when the lists contain unrelated items. If participants access their knowledge about list and within-list positions independently (see Friedman, 1990; Nairne, 1991), and both are required for correct performance, then better overall performance would be expected in the similar condition:

$$\text{Probability correct for similar} = .30 \times .80 = .24$$
$$\text{Probability correct for unrelated} = .50 \times .40 = .20$$

The point here is that the mnemonic effect of similarity, induced either by relational processing or by inherent item characteristics, will depend on the discrimination problem facing the individual. When the task requires discrimination among a fixed set of alternatives, embodied by equation 1 in the retrieval model, processing commonalities among items should lower the probability of sampling the correct target (i.e., there will be an increase in the amount of cue overload). In other environments, however, processing similarity eases the discrimination problem by restricting the search space, enabling one to sample from a smaller set of alternatives (e.g., sampling only from the list containing birds). As the size of the competitor set decreases, the denominator of equation 1 decreases as well. Whether relational processing will produce a net benefit or loss, as a consequence, will depend on the trade-off between the positive effects of delineating the search set and the negative effects of reducing within-set discriminability (see also Nairne & Kelley, 1999).

It is also conceivable that relational processing makes it easier to generate appropriate cues. Again, the retrieval model assumes that all instances of remembering are cue-driven: we use information in the present to decide what happened in the immediate and distant past. But such a model requires a mechanism for generating retrieval cues. In the feature model (Nairne, 1990a), which has been applied primarily to immediate memory, it is assumed that degraded records of prior processing remain available after list-processing for interpretation. To handle cue generation after delays, one commonly appeals initially to context; contextual information, which is assumed to evolve systematically over time, is used either as a cue or as a mechanism for generating cues-to-be-interpreted (e.g., Brown et al., 2002; Raaijmakers & Shiffrin, 1980). Because it induces the processing of similarities among items, relational processing is likely to augment the cue-generation process. Once a cue is generated and interpreted, it becomes a source for the generation of additional cues, either by virtue of simple associations or by fine-tuning the contextual information that is available.

The Benefits of Item-Based Processing

If the primary benefit of relational processing is to restrict the target search set, then the primary benefit of item-based processing is to ease the discrimination of items within that set. Processing "difference" presumably leads to traces with unique attributes—that is, traces with fewer overlapping features—which in turn makes it easier for the cue to access its appropriate target. Item-based processing reduces the amount of cue overload, or the extent to which any given list cue is predictive of many things, lowering the denominator of equation 1.

However, as discussed earlier, cue overload is not always a concern—it depends on the demands of the retention test. In free recall, the task is to recall all of the items from a just-presented list and output order is irrelevant. If relational processing successfully restricts the search set to items from the list, then a cue matching any or all of the list items is likely to be beneficial. A given cue, such as a degraded remnant of the third list item, does not need to sample its appropriate target (the third list item); any list item will do. Under such conditions, at least in principle, enhancing within-list distinctiveness may help one sample a particular item but not improve retention overall.

In most cases, however, relational processing is unlikely to restrict the search set entirely to list items. For example, knowing that a prior list contained "birds" may constrain the search set to birds, but nonlist category members are apt to be included as well. One needs item-based processing, as a result, to discriminate the "list" birds from the "nonlist" birds. Item-based processing, and the encoding of idiosyncratic features, also probably helps keep potential cues intact by lowering the likelihood of interference from subsequent material. Once again, the mnemonic effects of any kind of processing (relational processing, item-based processing, or their combination) will depend on a complex interplay among the cue–target match, the composition of the search set, and the availability of intact cues. As Hunt and McDaniel (1993) argue, it is probably best to encourage both relational and item-based processing to ensure good recall.

MODELS OF TEMPORAL DISTINCTIVENESS

Sampling in the retrieval model is based on relative comparisons between cues and possible targets in long-term memory, but the dimensions of comparisons are left unspecified. In principle, event A could differ from event B along a number of dimensions—orthographic, acoustic, semantic, and so on. Over the years, a number of theorists have suggested that time—specifically an item's temporal position of occurrence—is an important feature of an encoded trace: events can be remembered to the extent that they occupy unique or discrepant positions temporally. In this section, I briefly discuss some models of temporal distinctiveness and consider their relationship to the retrieval model proposed here.

The idea that temporal position is a crucial cue makes logical and empirical sense (see Brown & Chater, 2001). Logically, as noted earlier, recovery from episodic memory usually involves remembering that a well-known item occurred at a particular time and place; moreover, in most laboratory-based research, list items do not vary systematically along any dimension other than their time of presentation. Empirically, it is well established that temporal schedules of presentation affect recall probabilities in systematic ways. In free recall, for example, one can increase or decrease end-of-the-list recall (recency) by varying the amount of time that passes between each list item given a constant retention interval (e.g., Neath & Crowder, 1990). Alternatively, one can produce nearly equivalent recency effects across widely spaced retention intervals simply by holding the ratio of the interpresentation interval to the retention interval constant (Glenberg, Bradley, Kraus, & Renzaglia, 1983; Nairne, Neath, Serra, & Byun, 1997).

One of the more interesting properties of temporal variation and memory is scale invariance. Many of the classic phenomena of free and serial recall, such as recency, the shape of the serial position curve, and error distributions, retain their basic form across widely different time scales. Standard bow-shaped serial position curves, including the characteristic recency slope, have been detected for lists presented in under a second, as well as for lists presented over minutes, hours, days, or even months (see Baddeley & Hitch, 1993). What matters is not the absolute passage of time but, rather, the relative temporal positions of items sharing an episode. As discussed below, similar notions fall naturally out of the ratio-based retrieval model.

Models of temporal distinctiveness generally assume that memory traces are represented along a psychologically scaled (usually logarithmic) temporal dimension. A target trace is retrievable to the extent that its remembered position stands out, or is distinctive, along this temporal dimension. To calculate distinctiveness formally, for a given item one simply sums the distances between it and the remembered positions of all possible competitors. Because relative temporal position is what matters, the distinctiveness values are normalized: An item is especially recallable to the extent that it is distinctive compared to the other items on the list (Murdock, 1960; Neath, 1993). This last step, by design, helps to produce the property of scale invariance. As long as items occupy the same relative positions along the temporal dimension, their distinctiveness values will not change (despite changes in the overall passage of time).

There are actually a number of ways to determine temporal distinctiveness (see Brown et al., 2002, for a review). The methods differ primarily in terms of how relative temporal position is calculated. For example, the method just described is a *global* distinctiveness measure because all of the items in the competitor set contribute to the calculation. More *local* distinctiveness measures might consider only an item's immediate neighbors along the temporal dimension (e.g., Baddeley, 1976) or weight the distance values in such a way that psychologically distant neighbors play a less important role (Brown et al., 2002). All of these measures share the insight that distinctiveness is a relative concept; what matters is how the item differs from other items along a perceived dimension of similarity (temporal position).

The retrieval model of equation 1, of course, also stipulates that distinctiveness is a relative concept. Cues will sample particular targets to the extent that they match those targets better than other viable competitors. In this sense, the retrieval model embodies a kind of scale invariance. It is not the absolute cue–target similarity that matters, but the relative cue–target similarity. As long as the relative similarity values remain constant, the absolute cue–target match can change without changing the final distinctiveness values. (I return to this point briefly in the next section.) In fact, one current model of temporal distinctiveness, SIMPLE (Brown et al., 2002), relies on essentially the same ratio rule employed here to determine recall probabilities. In this case, however, the similarity dimension is temporally based: in attempting to recall an item that occurred t seconds ago, one computes the similarity between this duration and the remembered durations associated with each of the list items.

There is little question that time-of-occurrence information can serve as an important cue for retrieving and reconstructing the past. Temporal distinctiveness models have successfully accounted for a number of interesting empirical phenomena, including changes in the shape of the serial position as the length of the retention interval increases (e.g., Brown et al., 2002; Neath, 1993). Moreover, in stressing relative rather than absolute time, these models easily handle data that falsify traditional time-based decay models (see Nairne, 2002b, for a review). For example, psychologists have known for decades that retention sometimes improves with the passage of time (e.g., Turvey, Brick, & Osborn, 1970). Such a finding is clearly inconsistent with decay-based theories, but is easily explained by distinctiveness models. The relative discriminability of traces along the temporal dimension can remain the same with time, or even improve, depending on how the items in the competitor set are situated along the temporal dimension.

SUMMARY AND CONCLUSIONS

Mnemonic distinctiveness, as defined here, is a property of a cue in context. It refers to the ability of a cue to access a particular target in a particular context. As implemented in the retrieval model, correct target sampling depends on two factors: (1) the functional match between the current retrieval cue and the target trace, and (2) the functional match between the cue and the remaining members of the target competitor set. Neither of these factors, by itself, is sufficient to explain target recall—retention performance will always depend on both.

As shown throughout, the retrieval model can account for a number of benchmark phenomena in the distinctiveness literature. The prototypical distinctiveness effect, the von Restorff (or isolation) effect, was attributed primarily to cue overload: cues that match unusual events will tend not to match other events in the same context. Assigning a retrieval locus to the phenomenon, among other things, helps to explain performance levels for both isolated and background items, and accounts for why the effect remains strong for isolated items occurring early in a presentation sequence. The retrieval model also provides a nice conceptual framework for understanding the effects of processing similarity and difference on retention. The net advantage of processing similarity and difference can seem paradoxical, but not when the full discrimination problem facing the individual is considered. Correct target sampling depends not only on one's ability to discriminate among the items in the retrieval set but also on the ability to restrict the set of items to be considered. Processing similarity may impair within-set discriminability, but it can limit the search set by restricting its contents to items that vary along the similarity dimension.

The retrieval model has implications as well for general memory theory. Students of memory have a proclivity for making broad statements about what is best for retention, and the retrieval model places some important constraints on such statements. For example, I have written in detail elsewhere about the commonly accepted "principle" that memory depends directly on the similarity, or match, between retrieval cues and targets, as encoded (e.g., Nairne, 2002a). Although the model specifies that correct target selection is directly proportional to the cue–target match, consideration of the match alone cannot predict performance. In fact, under the right circumstances, increasing the cue–target match can improve performance, produce no effect, or even lower performance.

Suppose that people are shown a list of homophones for study (e.g., *pare, pair, pear*), presented both visually and aloud. At test, the task is to recall the item that occurred in third serial position. In the first condition, no retrieval cues are provided; in a second condition, the sound of the third item (*pear*) is given as an additional retrieval cue. The similarity, or match, between the retrieval cue and the encoded target is clearly increased in this second condition (assuming that people encoded the sound of the item during initial presentation), but it is doubtful that performance will improve. The sound of the item provides no distinctive information about which item occurred—all of the items on the list share the same sound. It is not the absolute cue–target match that matters, but the relative discriminability of the cue.

It is also easy to imagine situations in which adding to the cue–target match might hurt subsequent retention. Suppose, for instance, that we add an "overloaded" feature to the cue—that is, we add a feature that is shared by recall candidates that would not otherwise have been considered. (The addition of a salient rhyming or categorical feature, for example, might recruit new members into the competitor set.) Again, we have increased the similarity, or match, between the retrieval cue and the target trace, but the difficulty of the discrimination problem has been increased as well. To improve performance, it is not matching features per se that are needed (although the retrieval model requires some minimal cue–target match in the numerator); it is the presence of features that help one discriminate the correct target trace from incorrect competitors.

Similar arguments apply as well to proposals about the benefits of relational and item-specific processing (Hunt & McDaniel, 1993) or levels of processing (Craik & Lockhart, 1972). Encoding manipulations, by themselves, cannot be used to predict performance, nor can one speak of distinctive processing outside of a particular fixed retrieval environment (one in which both the cue and the members of the competitor set are specified). The processes of encoding, by definition, determine the variety and quality of trace features, but trace characteristics by themselves do not determine memory. It is the ability of the operative retrieval cue to access that trace that determines retention and, as argued throughout, it is the relative predictability of the cue that matters.

Of course, the idea that remembering is based on the relative predictability of cues is not new in the memory literature (e.g., Jacoby & Craik, 1979), although its implications have often been overlooked. In particular, it speaks to the proper definition of distinctiveness. As noted in the chapter opening, *distinctiveness* has been defined in various ways over the years—for example, as a property of a stored trace, a retrieval cue, or as a type of processing (Hunt, Chapter 1 this volume; Schmidt, 1991). Yet, to the extent that distinctiveness is considered to be a measure of memory, it can be none of these things. Distinctiveness cannot be a fixed property of a cue, or of a target trace, or even of an interaction between a given cue and a given target. It is best considered to be a property of a cue in context: Given a fixed set of alternatives, a measure of distinctiveness can be assigned to a particular cue with respect to a particular set of alternatives.

ACKNOWLEDGMENTS

Thanks to Ian Neath for useful discussions, and the editors, Reed Hunt and Jim Worthen, for their comments on the chapter text. Correspondence about this chapter can be addressed to the author: nairne@psych.purdue.edu.

NOTE

1. Placing the locus of the isolation effect at retrieval does not imply that encoding is unimportant, only that the mnemonic value of the encoded record depends on the retrieval context. Obviously, how an item is encoded will determine its ultimate discriminability within any given retrieval environment and, therefore, cannot be ignored.

REFERENCES

Anderson, J. R., & Schooler, L. J. (2000). The adaptive nature of memory. In E. Tulving & F. I. M. Craik (Eds.), *The Oxford handbook of memory* (pp 557–570). New York: Oxford University Press.

Baddeley, A. D. (1976). *The psychology of memory*. New York: Basic Books.

Baddeley, A. D., & Hitch, G. J. (1993). The recency effect: Implicit learning with explicit retrieval? *Memory & Cognition, 21*, 146–155.

Brown, G. D. A., & Chater, N. (2001). The chronological organization of memory: Common psychological foundations for remembering and timing. In C. Hoerl & T. McCormack (Eds.), *Time and memory: Issues in philosophy and psychology* (pp. 77–110). Oxford, UK: Oxford University Press.

Brown, G. D. A., Neath, I., & Chater, N. (2002). *SIMPLE: A local distinctiveness model of scale-invariant memory and perceptual identification.* Manuscript submitted for publication.