Journal of Experimental Psychology:
Learning, Memory, and Cognition
1994, Vol. 20, No. 1, 223–228

0278-7393/94/$3.00

Defining the Knowledge Units of a Synthetic Language: Comment on Vokey and Brooks (1992)

Pierre Perruchet

Vokey and Brooks (1992) reported a set of experiments intended to demonstrate that judgments of grammaticality are determined by two characteristics of the test items: their similarity with a specific study item and their conformity with an abstract representation of the generative grammar. I argue that both effects may be encompassed within a unified account, which requires neither a specific-item retrieval process nor an abstractive capacity. My basic assumption is that the primary knowledge units are not whole strings of letters, as postulated in models relying on specific similarity or abstraction, but rather fragments of 2 or 3 letters. Partial memorization of these small units provides a convenient account of the whole pattern of Vokey and Brooks's findings because study items have more units in common with similar than with dissimilar test items, and likewise with grammatical than with ungrammatical ones.

Vokey and Brooks's article (1992) aimed at comparing the explanatory power of two general positions about how people perform in the artificial grammar paradigm. According to the abstractionist position, of which Reber (1967, 1989) is one of the more active advocates, subjects abstract from the study strings the rules, or a subset of the rules composing the generative grammar, then assess the well-formedness of new strings as a function of their conformity to these rules. In the contrasting position, initially proposed by Brooks (1978), people judge the grammaticality of new strings as a function of their similarity to the stored representation of a specific study string. This strategy would be efficient because, the author argued, specific similarity is confounded with grammaticality in standard conditions.

The rationale of the experiments reported in the Vokey and Brooks (1992) article was to make independent the usually confounded factors of specific similarity and grammaticality, in order to assess the size of the effect of each factor on grammaticality judgments. Four lists of test items were constructed. Each item from the *close/grammatical* and *close/nongrammatical* lists differed from a specific study string by only one letter, and each item from the *far/grammatical* and *far/nongrammatical* lists differed from any study string by at least two letters. Letters differentiating test items from study items violated the transition rules only for the nongrammatical lists. In four experiments involving different grammars and conditions, the authors obtained a reliable effect of specific similarity on grammaticality judgments. As expected, close items were more often classified as grammatical than far items. In three of these experiments, the grammaticality factor also had a significant, and usually additive, effect. These results were offered as support for the contention that the similarity of test items with a specific training item partially determined subjects' judgment, in addition to and independent of abstract rule knowledge.

The Basis for a Reappraisal

It is worth noting that the two modes of processing combined by Vokey and Brooks (1992) in their framework are grounded on the postulate that the learners' primary knowledge units match the units conceived and generated by the experimenter, namely, the whole letter strings. This postulate is inherent to the abstractionist viewpoint, insofar as this viewpoint is centered on a process supposedly devoted to providing a tacit analysis of the strings into smaller, derived units (Mathews, 1990; Reber, 1989). Likewise, the nonanalytic, analogy-based processing advocated by Brooks (1978) is thought to be engaged only when subjects handle the letter strings as a whole.

However, several reasons militate for another starting assumption, namely that the knowledge units formed by subjects when they encounter an artificial language are parts of the items, such as fragments of two or three letters. Note first that postulating that a string such as *MVXRVMT* (most of the strings used by Vokey and Brooks (1992) were seven letters long) constitutes a functional unit, that is, forms a representation which is encoded, stored, and retrieved in an all-or-nothing manner appears highly counterintuitive. Introspective analysis suggests that the previous string will naturally be segmented, for instance, into (*MVX*) (*RV*) (*MT*) or (*MV*) (*XR*) (*VMT*).

At least two categories of experimental results support intuitive evidence. The first pertains to the coding of items during the study session. For example, when subjects are asked to write down the study items, they frequently reproduce the strings as separate groups of letters (Servan-Schreiber & Anderson, 1990). In the same vein, verbal reports of subjects asked to give verbal instructions to a yoked partner during the

Preparation of this article was supported by the Centre National de la Recherche Scientifique and by the Université René Descartes. I thank Robert Mathews, Arthur Reber, and John Vokey for their very helpful comments on an earlier version of this article.

Correspondence concerning this article should be addressed to Pierre Perruchet, LEAD, Faculté des Sciences, Université de Bourgogne, 6 Bd Gabriel, 21000, Dijon, Cedex, France.

Table 1
Mean Number of Initial and Terminal Trigrams Displayed in Study Phase That Were Included in Test Items, as a Function of the Test Lists Used in Experiments 1 and 4 of Vokey and Brooks's (1992) Study

	Grammaticality		
Similarity	Grammatical	Nongrammatical	*M*
Close	4.16	3.31	3.73
Far	3.12	2.25	2.69
M	3.64	2.78	—

study phase essentially refer to specific bigrams or trigrams (Mathews et al., 1989).

A second category of experimental evidence concerns the type of retrievable information in implicit and explicit subsequent tests. There are converging data showing that the knowledge underlying performance in an anagram task (Perruchet, Gallego, & Pacteau, 1992; Reber & Lewis, 1977) and in well-formedness assessments (Dienes, Broadbent, & Berry, 1991; Dulany, Carlson, & Dewey, 1984; Perruchet & Pacteau, 1990; Servan-Schreiber & Anderson, 1990) essentially consists of small fragments of the study strings. Explicit measures of memory for the study material, as assessed by free recall (Reber & Allen, 1978) and recognition (Perruchet & Pacteau, 1990) tests, also testify for the primacy of bigram and trigram knowledge. It is worth adding that all of these tests are sensitive to positional salience and to the frequency of occurrence of fragments. Unsurprisingly, bigrams or trigrams placed in first or last positions within the strings are privileged (Reber & Lewis, 1977) and frequent units are better memorized than unfrequent units (e.g., Perruchet & Pacteau, 1990). Both of these effects are typical of list learning and may hardly be reconciled with the claim that a whole letter string has an unitized representation.

Now, let us suppose that subjects exclusively ground their grammaticality judgments upon this fragmentary knowledge. Some of the previously mentioned studies (e.g., Dulany et al., 1984; Perruchet & Pacteau, 1990) lead us to anticipate that this hypothesis accounts for the variance in performance linked to the grammaticality factor in the Vokey and Brooks (1992) data. Indeed, analyses in the next section confirm this prediction, thus making the abstractionist side of the Vokey and Brooks' interpretative system unfounded.

Although more difficult to anticipate from available literature, the following analysis also shows that memorizing the small units making up the study strings accounts for the variance in performance linked to the specific similarity factor as well, because training items have more units in common with close test items than with far test items. This finding leads us to consider the claim for the role of specific similarity (the second side of Vokey and Brooks's (1992) interpretive framework) as also unfounded. In summary, the data provide evidence that the pattern of performance that Vokey and Brooks interpreted as support for a framework combining abstraction processes and specific similarity judgments may be conveniently accounted for by a single, unitary model, positing the primacy of small units of knowledge.

Empirical Evidence for a Unified Account

Providing a quantitative demonstration that both grammaticality and specific similarity of test items are confounded with the frequency of their constitutive units requires units to be empirically defined. In the following analyses, I focus upon initial and terminal trigrams. Indeed, the previously cited studies (especially Mathews et al., 1989, and Reber & Allen, 1978) concur to designate these units as among the most representative of the knowledge acquired in learning artificial grammar.

Choosing trigrams as units of analysis does not mean that subjects' units are thought to be trigrams in all cases. There is evidence that actual units may include two or more than three letters, especially in some cases such as repetition or alternance. Likewise, focusing upon initial and terminal units does not entail that subjects rely exclusively on these units. Presumably, the size and the position of the relevant units depend on a variety of factors, such as their intrinsic salience, and is prone to within- and between-subject variations. But for obvious reasons, it is not possible to consider all the various pieces of knowledge an individual subject may acquire in a given situation. Note that this limitation is not really damaging with regard to the present analysis, the objective of which is not to account for fine-grained individual performance.

Let us consider the first test item from the close/grammatical test list for subjects trained on List 1 in Experiments 1 and 4 (see Vokey & Brooks, 1992; Table 1). Its initial trigram (*MXR*) initiated 5 training items (*MXRVXT, MXRTMVR*, etc.) and its terminal trigram (*MXT*) ended one training item (*VXVRMXT*). In the present analysis, the first test item was attributed a score of 6 (5 + 1). I computed similar scores for all of the test items in each of the 4 test lists. The mean resulting scores are reported in Table 1.

Inspection of Table 1 reveals that items from grammatical lists scored higher than items from nongrammatical lists, a pattern that could be anticipated from prior similar analyses. More informative is the fact that items from close lists scored higher than items from far lists. This means that close items, in comparison with far items, included parts that were more often presented in the training items.

Table 2 shows that the material used in Experiments 2 and 3 exhibited the same pattern as that used in Experiments 1 and 4. (All of the values are lower because there were fewer study items in Experiments 2 and 3; however, only relative differences are relevant here.) The differences between grammatical and nongrammatical items on the one hand, and close and far items on the other hand, are manifest for test items generated by substitution as well as for test items generated by the addition of a letter to the study strings.

Two additional trends warrant notation. First, the differences between marginal values are of the same order for grammaticality and similarity factors. Grammatical items scored approximately 40% higher than nongrammatical items, and close items scored approximately 40% higher than far items. Second, direct examination of the entries shows that the effects of the two factors are approximatively additive. These trends appear in the three 2 × 2 tables with striking consistency. They provide evidence that the frequency distribution of initial and

Table 2
Mean Number of Initial and Terminal Trigrams Displayed in Study Phase Included in Test Items, as a Function of the Test Lists Used in Experiments 2 and 3 of Vokey and Brooks's (1992) Study

	Substitution			Addition		
	Grammaticality			Grammaticality		
Similarity	Grammatical	Nongrammatical	*M*	Grammatical	Nongrammatical	*M*
Close	2.06	1.56	1.81	2.58	1.56	2.07
Far	1.56	1.06	1.31	1.62	1.06	1.34
M	1.81	1.31	—	2.10	1.31	—

Note. Each study string served to generate two test strings. One test string was generated by substituting one letter of the study string. The other test string was generated by adding one letter to the study string.

terminal trigrams of study items is especially well-suited to account for the general pattern of Vokey and Brooks's (1992) data, insofar as grammaticality and specific similarity factors also have approximately equal and additive effects on subjects' performances.

It could be argued that the confoundings revealed here are not strong enough to account for the differences actually observed in performance. This argument has a weak a priori likelihood, to say the least, because both of the factors manipulated by Vokey and Brooks (1992) had only moderate effects. However, simulations of performance were run to directly rule out this potential objection.

Simulating performance implies the choice of a decision rule for grammaticality judgments. Unfortunately, we have only poor insights about the way subjects integrate and weigh the different components of information available to them. Weighing these components in order to optimize fitting between simulated and observed data without independent justification would considerably lessen the impact of the simulation. To avoid this potential flaw, performance was simulated with decision rules involving either initial or terminal trigram knowledge. This quite partial basis for judgment was found to be sufficient to generate performances matching the observed ones fairly well.

As a case in point, a simulation of performance for Experiments 1 and 4 was run with a decision rule positing that only the test items ending with a trigram that ended at least one study item were grammatical. Despite its simplicity, this decision rule classified as grammatical many more items from the grammatical lists than from the nongrammatical lists (.55 vs. .09). Likewise, applying this decision rule differentiated performance on close and far lists. Simulated proportions of close and far items classified as grammatical were respectively .42 and .22. It is worth noting that the difference between these values (.20) is of the same order as that between the values actually observed (.12 in Experiment 1; .21 in Experiment 4). Thus, differences in grammaticality judgments for test strings which are similar or dissimilar to one specific, individual study item do not entail that subjects rely on specific similarity. The pattern of results may be accounted for by assuming that people label as "grammatical" any item ending with the same trigram as a study item (of course, this does not mean in any way that subjects in fact focus on terminal trigrams at the expense of other fragmentary knowledge).

This analysis leads us to assert that exclusive reliance on componential information can account for the overall variance in performance elicited by the two factors manipulated by Vokey and Brooks (1992), namely specific similarity and grammaticality. Is the same process able to account for the more fine-grained results of Vokey and Brooks's article and for other findings recently published elsewhere by the same authors (Brooks & Vokey, 1991)?

The Fine-Grained Results of Vokey and Brooks (1992)

In their abstract, Vokey and Brooks (1992) mentioned three points in addition to the main finding discussed thus far. Their last two points (labeled *b* and *c* in their abstract) may be viewed as trivial implications of any interpretation positing a single intervening process. Point b stipulated that "variation in the effect of specific similarity did not result in compensatory variation in grammaticality" (p. 328); in other words, changes in learning or retrieval conditions may lead to simultaneous increases or decreases in the effects of the two variables manipulated by Vokey and Brooks. Point c referred to the fact that the "differential reliance on the two knowledge resources was not under good instructional control" (p. 328), a claim stemming from the fact that instructing subjects to judge from grammaticality rules or from specific similarity had no or only minor effects on performance. If, as argued here, neither of the two hypothesized processes is effectively engaged by subjects, then it is obvious that any attempt to modify their balance by manipulating experimental variables or instructions would be doomed to failure.

Point a of Vokey and Brooks's (1992) abstract stipulated that "better item memory resulted in smaller rather than larger effects of specific similarity on judgments of grammaticality" (p. 328). This conclusion stems from the results of Experiments 2 and 3, in which standard conditions of training were contrasted with conditions devised to promote individual item memory. For instance, each training item was associated with a mnemonic phrase (e.g., *MTTTTVT* was associated with "Montreal's Thousands Take The TV Times"). This kind of manipulation improved recognition memory for items and decreased the effect of specific similarity. This result is difficult to encompass within the present account. However, it must be realized that this account is intended to be relevant for the standard training conditions. The training conditions described previously notably depart from the conditions in use in other grammar learning studies, and more generally, in the implicit learning area, and hence the resulting pattern of performance cannot be damaging in any case for the validity of the interpretation proposed here.

About Brooks and Vokey (1991)

Brooks and Vokey (1991) reported an experiment in which a group of subjects was submitted to a procedure similar to that used in the target article of this commentary, except that all of the letters of the test items were changed in a consistent way (e.g., *M* was always replaced by *Q*, *V* by *Z*, and so on; note that the letters of the study items were left unchanged). The authors showed that the performance on these so-called *changed letter set* items reliably differed for lists derived from grammatical and nongrammatical test items and (at least to the same extent) for lists derived from close and far test items. They inferred from this result that transfer may be accounted for by two independent processes, respectively relying on (a) the knowledge of abstract rules extracted from a pooled representation of items, as advocated by Reber (e.g., Reber, 1989) and (b) the abstract or relational similarity of test items with a specific study item.

This article has dramatic consequences for the interpretation of the Brooks and Vokey (1991) data because the 1991 study involved the same material that was later used in Experiments 1 and 4 of Vokey and Brooks (1992). This means that both sets of studies shared the same confoundings. In particular, the notion of abstract or relational similarity propounded by Brooks and Vokey to account for the better transfer of items derived from close test items than from far test items is deprived of its main empirical support, resulting from the fact that, as demonstrated previously, close and far items differed not only by their degree of similarity with a specific study item, but also by the number of the fragments they had in common with study items.

However, the occurrence of a transfer to a new letter set raises some problems for the account put forward here as an alternative to Brooks and Vokey's framework. Indeed, the amount of relational information which may be abstracted from small units is quite scarce. For instance, the two letters from a bigram can only be the same or different. This kind of information about the structure of the test material may account for some transfer effects; for example, a principle such as "a string may end with a bigram composed of two identical letters" can be applicable to another letter set. Although more relational information may be abstracted from a trigram, it must be understood that positing the primacy of small units of knowledge makes the explanation of a large amount of transfer difficult. Hence, it is crucial to assess the size of the effects of transfer actually observed.

In the Brooks and Vokey (1991) experiments, the proportion of correct responses in the changed letter set condition was .555, a value statistically lower than the value obtained in the same letter set condition. This value exceeded the .50 correct proportion corresponding to random responding. But this comparison has limited validity. A more reliable procedure consists of comparing the performance of the transfer group to the performance of a control group (a group that had not previously been presented with the grammatical items in the study phase). Brooks and Vokey's design did not include such a control, so this comparison can only be drawn from the performances collected in similar experiments. As a case in point, Dulany et al. (1984) obtained a proportion of .555 correct in their own control group, exactly the same value as Brooks and Vokey found for their transfer group! Thus, the reported data, far from demonstrating that transfer is "excellent" and "remarkable" as claimed by Brooks and Vokey (1991, p. 320), failed to demonstrate that transfer actually occurred.

Even if we take for granted that the present results, together with related data from prior literature,[1] hint at a positive transfer to a new set of letters, the effect does not appear to be strong enough to prompt questioning of a model positing that subjects faced with a synthetic language in implicit conditions of learning essentially process small units of knowledge.

Abstraction-Based or Memory-Based Interpretation?

It is worth clarifying the status of the present interpretation with regard to the pervasive opposition between abstraction-based and memory-based models of human learning.

At first glance, the focus of this interpretation on componential information makes it close to the abstractionist models. It is reminiscent of a class of models which emerged in the categorization learning literature in the middle of the 1970s as an alternative to the models emphasizing the role of prototypes in category representation. Hayes-Roth and Hayes-Roth (1977), Neumann (1974), and Reitman and Bower (1973) propounded models that postulated that subjects faced with a study exemplar abstract and store in memory not only its component properties, but also some or all of the combinations of these properties. These models also explained data that supported the prototype models; but, unlike the latter, they were sensitive to the idiosyncratic information in exemplars, just like actual subjects (see Barsalou, 1990, for a discussion).

---

[1] There are two other studies that investigated transfer to a new set of letters (Mathews, Buss, Stanley, Blanchard-Fields, Cho, & Druhan, 1989; Reber, 1969). They are not more demonstrative than the Brooks and Vokey article because again they did not include a control group receiving no prior training with structured strings, which would be needed to reliably assess the occurrence and, if any, the importance of transfer effects.

Mathews, Buss, Stanley, Blanchard-Fields, Cho, & Druhan (1989) noted that, when no feedback was given on the correctness of response during transfer (i.e., in the standard test conditions in grammar learning), performances "deteriored greatly when letter sets were changed" (p. 1094). On the other hand, Reber (1969) obtained no reliable decrease in performance after changing a letter set. But this result was obtained in a rote memory task (instead of the usual grammaticality judgments), a change which notably alters the meaning of the results. Indeed, several factors may have had beneficial effects on transfer performance independent of transfer as related to the deep structure of the grammar underlying the to-be-learned items. For instance, subjects probably acquired general memory strategies in the study phase, which can be subsequently applied to whatever the specific material. Another factor, is that changing letters composing the to-be-learned items removed the effects of proactive interference.

Although there is an obvious parallel between the idea that subjects abstract and store a conjunction of properties and the present emphasis on bigram and trigram knowledge, differences are notable. The basic components of information processing in artificial grammar settings are disjunctive parts of the physical items, whereas in the categorization literature, they are a combination of item properties (e.g., size and color). This entails that the psychological processes postulated in the former case are far simpler that those postulated in the latter case. For instance, the storage demand is strikingly different. For example, a five-letter string generated by an artificial grammar setting will typically add two units (one bigram and one trigram) in memory. On the other hand, an exemplar containing five properties requires the retention of 31 properties and the combinations of the properties ($2^5 - 1$). Even if one considers only the pairs and triplets, there are still 20 possible combinations of properties.

More importantly for the present concern, the coding processes generating these memory units are only remotely similar. Whereas abstracting and recombining elementary properties of items in category learning models require specifically oriented analytic processes, the fragmentation of the physical items generated by an artificial grammar setting may be conceived without assuming any sophisticated cognitive abilities. Instead of being the end product of analytical operations performed on the whole items, fragmentation may originate from a failure of the perceptual system to comprehend the physical or logical units as functional units. It is clear that this failure can hardly be assimilated into a genuine abstraction process, even if, in a formal but psychologically irrelevant sense, bigrams and trigrams are abstracted from the whole letter strings (see Mathews, 1991, and Perruchet & Pacteau, 1991, for a discussion).

In regard to the literature on categorization learning, which flourished during the 1970s, this present interpretation is in fact nearest to the instance-based models propounded by Brooks (1978) and Medin and Shaffer (1978) in theory. Brooks himself (Brooks, 1978, 1987) applied his model to artificial grammar learning situations, and Vokey and Brooks (1992) endorsed the same position in order to account for the effect of their specific similarity factor. My interpretation is consistent with the nonanalytic stance of the Brooks's (1978) model, and with its reliance on memory-based processes. The main departure between interpretations concerns the size of the functional units of knowledge in artificial grammar settings. While Vokey and Brooks only considered the whole string level, the alternative view emphasizes that the psychologically relevant units are sets of two or three letters.

In some respects, this change is not essential. Positing the whole letter strings as the basic knowledge unit is not required in order to respect the internal coherence of Brooks's framework. Thus, this article should be viewed more as an attempt to improve the Brooks (1978) general model rather than as a rebuttal.

This does not mean that the implications of the change are minor. On the contrary, changing knowledge units has dramatic empirical consequences. The previous discussion shows that the effect of the grammatical status of test items that are matched for their similarity to specific study items is now accountable from a nonanalytic standpoint. Parsimony of explanation is worth noting. A single factor is put forward here: whereas Vokey and Brooks (1992) called for two independent processes, abstraction and assessment of global similarity, to account for their data, I propose a model with a single process. Although the search for integrative, unified models sometimes leads to elaborate hybrid theories which pay for their enlarged scope by intrinsic complexity, the theory proposed here calls for *less* sophisticated processes than the Vokey and Brooks's model, insofar as it makes abstraction processes objectless.

Final Remarks

This article adds to an impressive body of recent evidence emerging from various domains that shows that memory of specific events may account for a large part of performance that was once thought of as testifying for abstractive mechanisms (see reviews in Jacoby & Brooks, 1984; Shanks & St. John, in press). Is it worth concluding that abstraction processes must be disgarded once and for all from human learning investigations in favor of memory-based processes? Of course not. Claiming that human subjects are unable to abstract rules from rule-governed environments would be inconsistent with immediate intuitive evidence, as well as with the very existence of sciences such as logics, linguistics, physics, and so on. The dual ability of the human mind to store specific instances and to abstract rules, which is at the core of the Vokey and Brooks's (1992) model as well as other models of learning (e.g., Berry & Broadbent, 1988; Logan, 1988; Mathews et al., 1989; Reber & Allen, 1978), can hardly be questioned.

Such a consensus raises a doubt about the usefulness of demonstrating that abstraction is not involved in a particular experimental setting, and hence questions the interest of this article. This reservation would be warranted if the ultimate aim of experimental investigations was to demonstrate that subjects are able to learn by memorizing episodes on the one hand, and by abstracting rules on the other hand. My own perspective is that the endeavor of laboratory research should be directed at elucidating the conditions required for one or the other modes of learning and at investigating their interactions. The Vokey and Brooks (1992) article can be misleading on both of these issues. First, it provides apparent support for the occurrence of abstractive mental operations during incidental conditions of learning, while other available data suggests that rule abstraction requires conscious and controlled information processing (e.g., Perruchet, in press; Shanks & St. John, in press). Second, it suggests that these two modes of learning have additive effects, while there is evidence for models positing other, more dynamic relationships (e.g., Mathews et al., 1989).

References

Barsalou, L. W. (1990). On the indistinguishability of exemplar memory and abstraction in category representation. In T. K. Srull & R. S. Wyer (Eds.), *Advances in social cognition: Vol. 3* (pp. 61–88). Hillsdale, NJ: Erlbaum.

Berry, D. C., & Broadbent, D. E. (1988). Interactive tasks and the implicit-explicit distinction. *British Journal of Psychology, 79,* 251–272.

Brooks, L. R. (1978). Nonanalytic concept formation and memory for instances. In E. Rosch & B. B. Lloyd (Eds.), *Cognition and categorization* (pp. 169–215). Hillsdale, NJ: Erlbaum.

Brooks, L. R. (1987). Decentralized control of categorization: The role of prior processing episodes. In U. Neisser (Ed.), *Concept and conceptual development: Ecological and intellectual factors in categorization* (pp. 141–174). Cambridge, England: Cambridge University Press.

Brooks, L. R., & Vokey, J. R. (1991). Abstract analogies and abstracted grammars: Comments on Reber (1989) and Mathews et al. (1989). *Journal of Experimental Psychology: General, 120,* 316–323.

Dienes, Z., Broadbent, D., & Berry, D. (1991). Implicit and explicit knowledge bases in artificial grammar learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17,* 875–887.

Dulany, D. E., Carlson, A., & Dewey, G. I. (1984). A case of syntactical learning and judgment: How conscious and how abstract? *Journal of Experimental Psychology: General, 113,* 541–555.

Hayes-Roth, B., & Hayes-Roth, F. (1977). Concept learning and the recognition and classification of exemplars. *Journal of Verbal Learning and Verbal Behavior, 16,* 321–338.

Jacoby, L. L., & Brooks, L. R. (1984). Nonanalytic cognition: Memory perception and concept learning. In G. H. Bower (Ed.), *The psychology of learning and motivation* (pp. 1–47). San Diego, CA: Academic Press.

Logan, G. D. (1988). Towards an instance theory of automatization. *Psychological Review, 95,* 492–527.

Mathews, R. C. (1990). Abstractness of implicit grammar knowledge: Comments on Perruchet and Pacteau's analysis of synthetic grammar learning. *Journal of Experimental Psychology: General, 119,* 412–416.

Mathews, R. C. (1991). The forgetting algorithm: How fragmentary knowledge of exemplars can abstract knowledge. *Journal of Experimental Psychology: General, 120,* 117–119.

Mathews, R. C., Buss, R. R., Stanley, W. B., Blanchard-Fields, F., Cho, J. R., & Druhan, B. (1989). Role of implicit and explicit processes in learning from examples: A synergistic effect. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15,* 1083–1100.

Medin, D. L., & Shaffer, M. M. (1978). A context theory of classification learning. *Psychological Review, 85,* 207–238.

Neumann, P. G. (1974). An attribute frequency model for the abstraction of prototypes. *Memory and Cognition, 2,* 241–248.

Perruchet, P. (in press). Learning from complex rule-governed environments: On the proper functions of nonconscious and conscious processes. In C. Umilta & M. Moscovitch (Eds.), *Attention and performance XV: Conscious and nonconscious information processing.* Cambridge, MA: MIT Press.

Perruchet, P., Gallego, J., & Pacteau, C. (1992). A reinterpretation of some earlier evidence for abstractiveness of implicitly acquired knowledge. *Quarterly Journal of Experimental Psychology, 44A,* 193–210.

Perruchet, P., & Pacteau, C. (1990). Synthetic grammar learning: Implicit rule abstraction or explicit fragmentary knowledge? *Journal of Experimental Psychology: General, 119,* 264–275.

Perruchet, P., & Pacteau, C. (1991). The implicit acquisition of abstract knowledge about artificial grammar: Some methodological and conceptual issues. *Journal of Experimental Psychology: General, 120,* 112–116.

Reber, A. S. (1967). Implicit learning of artificial grammars. *Journal of Verbal Learning and Verbal Behavior, 6,* 855–863.

Reber, A. S. (1969). Transfer of syntactic structure in synthetic languages. *Journal of Experimental Psychology, 81,* 115–119.

Reber, A. S. (1989). Implicit learning and tacit knowledge. *Journal of Experimental Psychology: General, 118,* 219–235.

Reber, A. S., & Allen, R. (1978). Analogic and abstraction strategies in synthetic grammar learning. *Cognition, 6,* 189–221.

Reber, A. S., & Lewis, S. (1977). Implicit learning: An analysis of the form and structure of a body of tacit knowledge. *Cognition, 5,* 331–361.

Reitman, J. S., & Bower, G. H. (1973). Storage and later recognition of exemplars of concepts. *Cognitive Psychology, 4,* 194–206.

Servan-Schreiber, D., & Anderson, J. R. (1990). Learning artificial grammars with competitive chunking. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16,* 592–608.

Shanks, D. R., & St. John, M. F. (in press). Characteristics of dissociable human learning systems. *Behavioral and Brain Sciences.*

Vokey, J. R., & Brooks, L. R. (1992). Salience of item knowledge in learning artificial grammar. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 18,* 328–344.

Received May 26, 1992
Revision received October 9, 1992
Accepted October 21, 1992 ■