Abstract Analogies and Abstracted Grammars: Comments on Reber (1989) and Mathews et al. (1989)

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Reber (1969, 1989a) and Mathews et al. (1989), in experiments on learning artificial grammars, reported good transfer to letter strings consisting of letters not used in the training stimuli, provided that the same grammar generated both training and transfer strings. They concluded from this that the transfer predominantly relies on abstract knowledge. An experiment is reported that shows much of the transfer to "changed letter-set" strings is due to abstract similarity between test strings and specific training stimuli (i.e., a string such as MXVVVM could be seen as similar to BDCCCB without implying that regularities common to a large number of training items had been abstracted). The conclusion of this article is that reliance on an abstract (relational) analogy to an individual item must be distinguished from reliance on knowledge of the structure of the grammar abstracted across many training items.

In a number of recent articles, artificial grammars have been used to study the way in which people learn complex regularities (e.g., Mathews et al., 1989; Reber, 1989a, reviewing the extensive work in his laboratory). In these studies, letter strings generated from an artificial grammar, such as those shown in Figure 1 and Table 1, are presented to learners. The extent to which the learners become sensitive to the regularities in the generating grammar is tested by asking them to sort new items generated by the grammar from similar strings that violate the grammar. Much of the interest in these materials has come from the claim that the learner more or less automatically acquires an abstract representation of the structure of the experienced material, which becomes the major basis of grammaticality judgments. Reber argued strongly for a separate, sophisticated, and tacit system that accomplished this abstraction for complex domains. Recent controversy has centered on Reber's claims that the abstracted knowledge is unconscious (Brody, 1989; Dulaney, Carlson, & Dewey, 1984, 1985; and with respect to the sophistication of the unconscious system, Lewicki & Hill, 1989; Mathews, 1991; Perruchet & Pacteau, 1990, 1991; Reber, 1989a, 1989b, 1990; Reber, Allen, & Regan, 1985).

However, the focus of the present comment is on a particular line of evidence used to support the assertion that grammaticality judgments are predominantly based on abstract knowledge. Both Reber (1969) and Mathews et al. (1989) have demonstrated very good transfer when subjects were trained on a set of strings generated using one set of letters and tested on a set of items written in a different set of letters, provided the same grammar was used to generate both sets of items. For example, the grammar shown in Figure 1 will produce all of the items listed in Table 1 as "same-letter training items" (first column) as well as the items listed as "grammatical transfer items" (second column). If the training items were in fact the items listed as "same-letter training items," then the training and the transfer set would be generated from the same letter set and by the same grammar, a condition referred to as same letter-set transfer. To produce "changed letter-set" stimuli similar to those used by Reber and by Mathews et al., each of the letters in the grammar would be systematically replaced by a different letter wherever it occurred. So for example, in all occurrences an M could be replaced by a Q, V by Z, X by J, T by F, and R by L. This would produce the correspondences shown between the "grammatical transfer items" and the training items for Subject 1 in Table 1: the same grammar but a changed letter set. In both studies, the transfer performance on the changed letter sets was not statistically distinguishable from the transfer performance on the same letter sets. Reber and Mathews et al. concluded that the excellent transfer with the changed letter sets was strong evidence that transfer was based on abstract knowledge, rather than on similarity to prior items. It is this claim that we wish to dispute.

There is no doubt that good transfer to items written in a different letter set entails abstraction in some sense. But it is possible that performance is based on similarity between the transfer string being tested and an individual training string. For example, a string such as MXVVVM could be seen as similar to BDCCCB in that they both start and end with the same letter and have a repeated letter triplet next to the end. We will refer to this possible similarity as an abstract analogy, or relational analogy, in contrast with literal similarity. For example, perceived similarity between MXVVVM and MTVVVM could be because of overlap of letters-in-position, because of the similar relations among letters, or both; this degree of similarity is an example of literal similarity. Perceived similarity between MXVVVM and BDCCCB could...
only be because of the more abstract correspondence of within-item relations among letters. However, both of these should be distinguished from an abstraction of the overall structure of the grammar. A learned structure is a representation of whatever commonalities have been noticed among the learning items; that is, the abstraction being referred to is an abstraction across the set of learning items. In contrast, the sense of the word *abstract* that captures the relations between the pair MXVWVM and BDCCCB could hold just as well among pairs of nongrammatical items (as indeed these are relative to the grammar in Figure 1).

This distinction follows that made by Gentner (1983) among literal similarity, analogy, and abstraction. Her problem was to develop a vocabulary that captures the sense of an analogy, such as “A battery is like a reservoir.” *Literal similarity* is a term that she reserved for pairs that overlap in many specific attributes in common (“The atom is like our solar system.”). *Abstraction* is a term to refer to systematic relations in a comparison such as “The atom is a central force system.” In abstraction, only some attributes and relations are utilized, presumably those that convey a “system of connected knowledge, not a mere assortment of independent facts” (Gentner, 1983, p. 162). In the current discussion, this use of the word *abstraction* most closely corresponds to an abstracted grammar.

Because neither Reber nor Mathews and his colleagues controlled the abstract similarity of their transfer strings to particular old items, it is logically possible that some portion of the transfer they observed is due to abstract analogies, rather than to an abstracted grammar. We are not quibbling by distinguishing between transfer by abstract analogy and transfer by abstracted grammars. If a large part of the transfer were due to reliance on abstract analogies, then it would be consistent with the position that an important part of the knowledge base with which people deal with complex regularities is distributed, consisting in routine analogy to prior episodes. Such a knowledge base could preserve many of the statistical properties of the domain as has been shown by models that rely on distributed representations such as those presented by Estes (1986), Hintzman (1986), Logan (1988), McClelland and Rumelhart (1981, 1985), Medin and Schaffer (1978), Nosofsky (1986), and Whittlesea (1987). The fundamental advantage of thinking about systemic knowledge as distributed across prior episodes is not avoidance of attributing abstractive ability to people (an ability that people undeniably do have, at least consciously). Rather, the advantages are that distributed knowledge gives a principled way of dealing with interactions among the instances from the domain and with variability in the learner's performance. One protection that people have against peculiar and poorly understood interactions in the world is their knowledge of very similar past episodes, instances that themselves may be the product of the same interactions and that may be poorly captured by whatever generalizations the learner has currently. The distributed items could as easily be thought of as extremely specific, context-dependent rules as well as prior episodes. The important point for knowledge representation is that, under some coding conditions, people are sensitive to details of context and processing and that this sensitivity can serve as a way of representing complex interactions. Arguments for the adaptive value of reliance on a distributed knowledge base have been presented by Brooks (1978, 1987), Jacoby and Brooks (1984), Kahneman and Miller (1986), and Ross (e.g., 1989), and in computer science by Shank (1982) and Kolodner (1988).

In the experiment in this article, we used materials in which the similarity of test items to specific training items was unconfounded from the grammaticality of the test items, variables that we believe were confounded in most previous studies of artificial grammars. This unconfounding allows us to compare the effectiveness of these two variables for controlling subjects' judgments of grammaticality of new items. These materials were used in a previous set of studies (Vokey & Brooks, in press) in which we found that both empirical variables, grammaticality and specific similarity, had an effect on the recognition and the grammaticality judgments of subjects within the same task. The specific similarity result accounted for at least as much variance as did the grammaticality variable. Furthermore, the specific similarity variable was of substantial importance even under training conditions that are similar to most of the conditions in the literature. Sensitivity to specific similarity was not restricted to special conditions that use an unusually small number of items or place a special burden of memorization on the learner. The focus of the previous article was on how the two underlying knowledge sources are coordinated at retrieval. The focus of the current comment is on whether the same relative contribution of similarity will occur when the item analogies are abstract.

### Empirical Variables of Specific Similarity and Grammaticality

To unconfound the variables of specific similarity and grammaticality, we need to produce both grammatical and nongrammatical transfer items, with some of each type being similar to particular training items and some of each type being relatively dissimilar to any of the training items. The
### Table 1

*Training Items Used for Same-Letter and Sample Changed-Letter Subjects and Grammatical and Nongrammatical Transfer Items for All Subjects in Lists 1 and 2*

<table>
<thead>
<tr>
<th>Training items used for same-letter subjects</th>
<th>Transfer items for all subjects</th>
<th>Training items used for sample changed-letter subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grammatical</td>
<td>Nongrammatical</td>
</tr>
<tr>
<td>MXRVXT</td>
<td>MXRMXT</td>
<td>QILZIF</td>
</tr>
<tr>
<td>VMTRRRR</td>
<td>VMTTRRRX</td>
<td>ZQFLLLL</td>
</tr>
<tr>
<td>MXTTRRR</td>
<td>VXTRRR</td>
<td>QIFLLL</td>
</tr>
<tr>
<td>VXVRMXT</td>
<td>VXVRVXT</td>
<td>ZIZLQIF</td>
</tr>
<tr>
<td>VXVRVM</td>
<td>VXVRVV</td>
<td>ZIZLZQ</td>
</tr>
<tr>
<td>VMRVVVV</td>
<td>VMRVYVM</td>
<td>ZQILZZZ</td>
</tr>
<tr>
<td>MXTMTRV</td>
<td>MXRTMXR</td>
<td>QILFQZL</td>
</tr>
<tr>
<td>VMXTRM</td>
<td>VMXTRXT</td>
<td>ZQLQJFL</td>
</tr>
<tr>
<td></td>
<td>QIL</td>
<td></td>
</tr>
<tr>
<td>VMRXVXR</td>
<td>VMRXVT</td>
<td>ZQLZJZL</td>
</tr>
<tr>
<td>VMRYM</td>
<td>MXRYM</td>
<td>QILZQ</td>
</tr>
<tr>
<td>VMRVMRVR</td>
<td>VMRMRVX</td>
<td>ZQLQJZL</td>
</tr>
<tr>
<td>VMRMVXR</td>
<td>VMRMVXT</td>
<td>ZQLQJZL</td>
</tr>
<tr>
<td>MXTVXT</td>
<td>MXTMXT</td>
<td>QILFQZJF</td>
</tr>
<tr>
<td>MVMXVXR</td>
<td>MVMXVXT</td>
<td>QILQJZL</td>
</tr>
<tr>
<td></td>
<td>QZJFL</td>
<td></td>
</tr>
</tbody>
</table>

**Note.** The same-letter training items were used as training items for the same-letter subjects and to generate the transfer items for both groups of subjects. The training items for the changed-letter subjects were produced by systematically substituting the set of letters in the same-letter training items with a new set of letters randomly selected for each subject. For hypothetical Subject 1, the transfer items in the top half of the table were close items and the transfer items in the bottom half were far items. For Subject 2, the reverse was true. The same close–far counterbalancing was also used for same-letter subjects.

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Table materials used in the current experiment and in two of the experiments by Vokey and Brooks (in press) are shown in Table 1.

As a criterion of similarity, we called any item “similar,” or “close,” if it differed from a training item by only one letter, and “dissimilar,” or “far,” if it differed by more than one letter from the most similar training items. Reading across any row of Table 1, it can be seen that for each of the same-letter training items, there was one close transfer item that was grammatical according to the grammar in Figure 1 and one close transfer item that was not. The nongrammatical transfer item, MTR, for example, was produced from the grammatical transfer item, MVR, by substituting the letter T for the V, resulting in an item that cannot be generated from the grammar, but which differs from the associated training item, MXR, by a single letter in the same position as that of the grammatical item. If, as in the current same-letter condition and in Vokey and Brooks, a subject was trained only on the 16 same-letter training items in the top half of Table 1, then the transfer items in the top half of Table 1 would be close items and the transfer items in the bottom half of Table 1 would be far items. In this way, we were able to produce both close and far grammatical items and close and far nongrammatical items, using the logical training items in the bottom of Table 1 for counterbalancing.

One half of our subjects—the same letter set or control subjects—were trained with the same-letter training items shown in Table 1. For subjects in the changed letter-set condition, the training items were produced by systematically substituting the set of letters in the same-letter training items
with a new set of letters randomly selected for each subject. Thus, the training items MVXTR might appear on the screen as QZJFL for one subject and as BCDGH for another. For a hypothetical Subject 1, after learning the training items shown, the transfer items in the top half of Table 1 would be close items and the transfer items in the bottom half would be far items. For a hypothetical Subject 2, with the training list shown, the reverse would be true. Note that close transfer items differ from far transfer items, not by being similar to any general characteristic of the training list, but by being individually similar to a specific item of the training list. In these materials, care was taken to ensure that, with the exception of the specific match, close items for a given subject were no more similar to the items of a given training list than were the far items. Thus, the variable of specific similarity is unconfounded with the generative grammar and hence the experimental variable of grammaticality.

Method

Subjects

Thirty-six young adults, 18 in each letter-set condition, served as subjects. Most were university undergraduates who volunteered their time; the remainder were solicited from the wider community and were paid $3.00 each to participate. Subjects were tested individually.

Materials

The structure of the experimental items was the same as those used in Experiments 1 and 4 of Vokey and Brooks (in press), which contains a more complete description of the material. In brief, 32 same-letter training items were selected from the set of all possible items, from three to seven letters in length, generated from the artificial grammar shown in Figure 1. Each of these training items was used to generate a grammatical and a nongrammatical transfer item. Transfer items of both types differed by a single letter in position from its respective training item, and differed by at least two letters in position from all other training items to ensure that it had one, and only one, close formal analogy among the training items. The nongrammatical items were produced by substituting a single (illegal) letter at the same-letter position in which the grammatical item differed from its matched training item. The training items were divided into two lists of 16 items each. Constraints imposed on the selection of items ensured that the two training lists were equally representative of the grammar and that the transfer items did not differ systematically from the training items. For each subject in the changed letter-set condition, the computer selected at random without replacement five letters from the set of consonants remaining after the five same letter-set consonants used in Table 1 had been removed. Each of these was then assigned at random to substitute uniquely for one of the letters used to produce the training items. Each subject was trained with only one of the two resulting training lists, but was tested on the complete set of 64 transfer items shown in Table 1.

Procedure

The training and test procedures were similar to those used in Experiment 1 of Vokey and Brooks (in press), except that all stimulus items and tasks were presented to the subjects on a computer display screen, rather than in booklets as had been used there. For training, each subject was assigned to one or another training list, such that one half of the subjects received Training List 1, and the remainder received Training List 2. The 16 training items so produced were then divided at random into four sublists of 4 items each. Each sublist was presented with the items oriented vertically in a random order and was repeated four times. Subjects were instructed to study the items and then to press a key on the computer keyboard (which cleared the items from the display) and attempt to recall the 4 items (or parts thereof) in any order on a piece of paper. Upon recalling as many or as much of each as they could, the subjects were instructed to turn the paper over and to press a key to present the same list of items again or, if all four presentations of a given sublist had been completed, a new sublist of 4 items. Between sublists the subjects were informed that a new list of 4 items would be presented. Subjects were not informed about the grammar, about the number of lists they were to receive, or that their task would consist of anything other than the training phase. Training was completely self-paced.

Transfer, every subject received the same 64 transfer items in the standard letter set shown in Table 1, which resulted in a changed letter set for the changed letter-set condition. Each item was presented twice, for a total of 128 judgments, although the subjects were not informed of this fact. All 64 items were presented first before any item repeated. For each subject, the 64 items were divided at random, twice, into eight lists of 8 items each. Each list was presented with the items listed vertically on the display screen. Each item was preceded by a pair of braces enclosing a space in which the subjects were to type their response to the item. Subjects were told that all the items they had seen during the training phase had been generated by a complex set of rules. They were not going to be told what those rules were, but they were going to receive lists of new items, some that were constructed to obey the same rules and some that were constructed specifically to violate the rules. Subjects in the changed letter-set condition were told further that all the letters composing the items had been changed. All subjects were told that their task was to indicate which of the items they believed obeyed or disobeyed the rules. At the top of the display was a summary of the response-scale the subjects were to use, ranging from 1, meaning sure does not obey the rules, through 2 and 3, meaning guess does not or guess does obey the rules, respectively; to 4, meaning sure obeys the rules. All other keyboard responses were ignored. Subjects could move freely among the items displayed for a given list, responding or changing their response to the items in any order they wished. After every item in a list had been given a response, a message appeared at the bottom of the display informing subjects that they could move on to the next list by pressing the space bar, although subjects were free to adjust their responses to the current list of items for as long as they wished. Subjects could neither move on to the next list until every item in the current list had been given a response nor could they move back to a list once they had pressed the key to advance to the next list. Responding was completely self-paced, and subjects were not informed about the number of lists they would receive or the frequencies of the alternatives. After completion of the 16 lists, subjects were interviewed informally about how they accomplished the transfer task.

Results

Table 2 shows the results of the transfer phase for both groups. The proportion of items labeled grammatical (scale responses guess it obeys the rules and sure it obeys the rules) were subjected to a three-way analysis of variance with subjects nested within letter-set condition, but crossing specific similarity and grammaticality as the random variate. Overall, subjects labeled an average of 46.7% of the items as gram-
mational, and the two letter-set conditions did not differ significantly in this regard, $F(1, 34) = 1.27, MS_e = 0.48, p = .27$. The main effects of both grammaticality and specific similarity were significant at the $\alpha = .05$ level. As a whole, subjects produced significantly more grammatical responses to grammatical items ($M = 0.543$) than to nongrammatical items ($M = 0.391$), $F(1, 34) = 80.67, MS_e = 0.010$ and to close items ($M = 0.533$) than to far items ($M = 0.401$), $F(1, 34) = 97.78, MS_e = 0.006$, with two effects being additive, $F(1, 34) = 0.43, MS_e = 0.004, p = .84$. Specific similarity was the larger of the two effects, although not significantly ($z = .29$). Characterizing performance in terms of accuracy, the subjects scored an average of 57.6% correct, which rises to an average of 64.2% if, as we have argued for the materials in many of Reber’s experiments (e.g., Reber, 1969, 1989a), specific similarity is confounded with grammaticality (i.e., close grammatical items and far nongrammatical items).

As indicated by significant interactions of specific similarity and grammaticality with letter-set condition, changing the letters between training and test not surprisingly did influence transfer performance. As may be seen in Table 2, subjects in the changed letter-set condition were significantly less affected by the grammaticality of the items than were subjects in the same-letter condition, $F(1, 34) = 615, MS_e = 0.010$, scoring only 55.5% correct as compared with 59.7% correct in the same-letter condition. Similarly, they also were significantly less affected by the specific similarity of the items, $F(1, 34) = 4.17, MS_e = 0.006$. However, although of reduced magnitude, simple effects analyses revealed significant effects of both grammaticality, $F(1, 34) = 21.33, MS_e = 0.010$, and specific similarity, $F(1, 34) = 30.79, MS_e = 0.006$, for the changed letter-set condition, as is shown in Table 2. The corresponding simple effects for the same-letter condition were $F(1, 34) = 65.59, MS_e = 0.010$, and $F(1, 34) = 71.15, MS_e = 0.006$, respectively.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Grammatical</th>
<th>Nongrammatical</th>
<th>Effect size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Close</td>
<td>Far</td>
<td>Close</td>
</tr>
<tr>
<td>Changed letters</td>
<td>.585</td>
<td>.500</td>
<td>.495</td>
</tr>
<tr>
<td>Same letters</td>
<td>.636</td>
<td>.452</td>
<td>.417</td>
</tr>
<tr>
<td>Average</td>
<td>.611</td>
<td>.476</td>
<td>.456</td>
</tr>
</tbody>
</table>

Note. Effect-size estimates for grammaticality ($r_0$) and specific similarity ($r_s$) are point-biserial correlation coefficients.

Discussion

In this experiment, as in those by Reber (1969) and by Mathews et al. (1989), the subjects’ pattern of performance on the changed-letter transfer items is very similar to that on same-letter transfer items. This excellent transfer is remarkable and is not automatically dealt with by either an abstract or a distributive perspective. However, the point of the present comment is that this excellent transfer is not in itself evidence of reliance on an abstracted grammar. The fact that the similarity-to-old variable controls, if anything, more variance than the grammaticality variable makes it plausible that specific item analogies are an important contributor to transfer even under conditions of changed letter sets.

Mathews and his colleagues (1989) observed that their experimental groups that had experienced two prior letter-set changes did not perform significantly better on transfer to an additional new set of letters than did subjects who had experienced no prior changes. These investigators expected that the subjects with prior letter-set transfers would have done better if they had been attempting to consciously abstract the invariant properties of the grammar. They attribute this lack of difference to the automatic quality of implicit abstraction, apparently meaning the implicit development of abstract knowledge. It is not obvious to us why one would not also expect implicit abstraction to be better with several letter changes. It seems at least as possible that both groups were partly relying on generalization around instances, or at least very specific rules. However, in absence of a well-specified theory on either side, this stands only as a suggestion. Again, what is not at issue is that subjects acquire some abstract knowledge. Mathews et al. provided convincing evidence that their subjects’ verbalizations contain valid knowledge of the grammar. Verbal representation of regularities is clear evidence of abstraction, but obviously not of the tacit abstraction that is at issue in these experiments. The variance controlled by the grammaticality variable in the current experiment could also be taken as evidence of reliance on knowledge abstracted during the training phase. But, as is discussed in Vokey and Brooks (in press), the large effect of grammaticality in the current study could instead be attributed to the distributive mechanism of pooling items at retrieval. In situations with a single training phase and training items that are all “grammatical,” our preference is for explaining the grammatical, and the two-letter-set conditions did not differ significantly in this regard, $F(1, 34) = 1.27, MS_e = 0.48, p = .27$. The main effects of both grammaticality and specific similarity were significant at the $\alpha = .05$ level. As a whole, subjects produced significantly more grammatical responses to grammatical items ($M = 0.543$) than to nongrammatical items ($M = 0.391$), $F(1, 34) = 80.67, MS_e = 0.010$ and to close items ($M = 0.533$) than to far items ($M = 0.401$), $F(1, 34) = 97.78, MS_e = 0.006$, with two effects being additive, $F(1, 34) = 0.43, MS_e = 0.004, p = .84$. Specific similarity was the larger of the two effects, although not significantly ($z = .29$).

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Effect sizes were estimated by converting the $F$ ratio for each effect to a point-biserial correlation coefficient. To test for differences in effect magnitude, the coefficients were converted to $z$ scores using the Fisher $r$-to-$z$ transformation, and the difference between them was divided by the standard error of such differences to yield a $z$ score that was treated in the usual manner.
icality variable in terms of retrieval pooling. However, there is nothing in the current data that picks between the two interpretations.

**Comments on Perruchet and Pacteau (1990)**

Our final comments on the issue of abstractness of operative knowledge are directed to a recent article by Perruchet and Pacteau (1990). These investigators hypothesized that grammaticality judgments can be accounted for by fragmentary, conscious knowledge of pairs of letters, a position similar to that taken by Dulaney, Carlson, and Dewey (1984). In their first study, subjects who studied only isolated pairs of letters that were extracted from grammatical strings performed as well on distinguishing grammatical from nongrammatical strings as did a conventional study group, provided that test strings with violations in the first position were removed. In their third study, subjects received standard training and then were asked to recognize which pairs occurred anywhere in the training strings. In a simulation of performance in the first studies, based on these recognition scores for bigrams, subjects were hypothesized to call any string nongrammatical that contained an unrecognized bigram. When recognition criteria were adjusted to correct for individual response biases, this simulated performance was very close to observed performance. The overall conclusion drawn from these studies was that knowledge of pairs of letters, with minimal information about permissible location of the pairs, was sufficient to account for grammaticality judgments. On this basis, Perruchet and Pacteau (1990) raised question about the abstractness of the knowledge involved: "Fragmentary knowledge of the pairs of consecutive letters included in the items may hardly be considered as abstract and complex, inasmuch as it involves only pairwise association learning" (p. 271).

If the operative form of the subjects' knowledge is largely isolated bigrams, then it runs counter to the type of explanation suggested in a distributive model. To directly address Perruchet and Pacteau's (1990) model with the current data, we would also have to have data on the recognition of bigrams, which were data we did not collect. However, inspection of the distribution of bigrams in our materials suggests that it will be difficult to fit our similarity-to-old variable by assuming that the close transfer items as a whole have more recognized bigrams in common with the training list than do the far transfer items as a whole. Given the multiple constraints on the experimental materials, the bigram frequencies are not perfectly matched in the two training lists, although they were considerably closer in the two transfer lists (which is relevant to a close–far difference). But given Reber's (1989a) prior emphasis on the importance of bigrams, we did try to limit the distributional differences between the two sets of bigrams. This at least decreases the chances that there would be a close correspondence between bigram recognition and the effect of the similarity variable.

However, even if a close relation between the recognition of bigrams and performance on grammaticality judgments were found, this would not eliminate the possibility that the knowledge of the training strings being used by the subjects was organized into larger units. Both the performance on the recognition of bigrams and the performance on categorizing the test strings may have been based on partial retrieval of prior items. In the event that there were a close correlation between bigram recognition and grammaticality judgments, we would be tempted to test our interpretation by varying the availability of training items through the types of episodic variables used by Vokey and Brooks (in press).

But beyond this, it seems improbable to us that, when at least part of the subjects' job is to memorize strings, the only organization effectively available are the constituent bigrams. This may be the form of knowledge that subjects stress when asked for rules, but it need not be the only form of knowledge that they actually use when making grammaticality judgments of familiar-seeming strings. A comparable underreporting of the influence of item similarity in a categorical task is given in Allen and Brooks (1991).

Perruchet and Pacteau's (1990) main point, however, is still well taken. The knowledge actually relied on by subjects may be extremely fragmentary and consequently easy to miss for both the subject and the experimenter in the usual assessments of explicit knowledge. At the minimum, Perruchet and Pacteau have demonstrated that the modest performance shown by most subjects can be simulated by knowledge as simple as bigrams. Our point of disagreement is whether their evidence should be taken as showing that the organization of this fragmentary knowledge is less than would be required to produce an effect of variable, whole item retrieval.

**A Special Paradigm**

Obviously humans are capable of forming and using abstract knowledge. However, one cannot merely assume that the unquestioned existence of human abstract ability means that performance in this particular situation is based on abstract knowledge without forfeiting any possibility of discovering the conditions under which abstract knowledge is formed. There are several features of the experimental situation developed by Reber and his colleagues (1989a) that are very special and should be considered in evaluating the claim of tacit abstraction (i.e., abstraction in the sense of a representation of structural constraints across the whole set of training items). If substantial structural knowledge is formed under these conditions, then we have learned a great deal about the underlying ability that is not forced by the sheer existence of systematic cognitive activity in language, perception, and social behavior.

The special characteristics of Reber's (1989a) design that attract our attention are that the rules are extremely complex and there is only one short phase of training, which consists only of grammatical items. Because there are not repeated cycles of training with feedback and testing, there is a restricted opportunity to isolate contrastive patterns. Even Reber's and Dulaney et al.'s (1984) subjects who were given the rule instructions ("There are complex rules underlying these strings; it will be to your advantage in memorizing the strings to discover the rules.") were not exposed to nongrammatical strings in training that would have allowed them to discover contrastive patterns. These are not good conditions for deliberate abstraction and may not be good conditions for any
other kind of abstraction available in a short experiment. There is no prior reason why brief, noncontrastive training with very complex rules could not result in abstraction of commonalities, as Reber claims. But for these critical conditions, generalization among the training instances is at least a good competitor.

Some of the features of Reber's (1989a) paradigm parallel conditions of general interest. Clearly, there are areas of knowledge in which regularities are extremely complex and in which experiences with acceptable instances vastly outnumber those with unacceptable ones. The conditions under which language and social conventions are learned obviously are not primarily structured as a discrimination between the category of current interest and a definite set of well-formed alternatives, as is true for concrete object categories. However, the normal conditions for learning these areas of knowledge are probably more similar to those developed by Mathews et al. (1989) than they are to Reber's. Mathews and his colleagues provided extended training, opportunities for generation, interleaved testing and training, and partial feedback in some testing situations, all of which are true of most natural learning situations and all of which could be expected to influence the processes of learning. The results of their experiments demonstrated many of the same features as did Reber's: above chance transfer, transfer that did not differ between groups alerted to the existence of rules and those who had no reason whatever to be deliberately abstracting regularities (most impressively between the match and the edit groups), and transfer that was better than could be accounted for by easily elicited rule statements. The similarities in results give confidence that the learning being observed in the rest of the literature on artificial grammar is not a fragile phenomenon.

For the current article, however, it is interesting that Mathews et al.'s (1989) conditions also yield knowledge that is explicitly communicable. New subjects responding solely on the basis of rule statements given by subjects with conventional training performed well above chance. Mathews et al. suggest a synergistic relation between prior experience with particular instances of the grammar and subsequent attempts to explicitly learn the regularities. The prior experiences are presumed to play an important role in the generation of conceptual models of the grammar. To this plausible picture, we would add the caveat that an unknown part of the transfer, especially that not accounted for by verbalized regularities of the grammar, could be due to relational or abstract analogy to explicitly learn the regularities. The prior experiences are the basis of rule statements given by subjects with conventional literature on artificial grammar is not a fragile phenomenon. The similarities in results give confidence that the learning being observed in the rest of the literature on artificial grammar is not a fragile phenomenon.

References


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**1992 APA Convention “Call for Programs”**

The “Call for Programs” for the 1992 APA annual convention will be included in the October issue of the *APA Monitor*. The 1992 convention will be held in Washington, DC, from August 14 through August 18. Deadline for submission of program and presentation proposals is December 13, 1991. Additional copies of the “Call” will be available from the APA Convention Office in October.