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Implicit Acquisition of Abstract Knowledge About Artificial Grammar: Some Methodological and Conceptual Issues

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In this reply to comments by Reber (1990) and Mathews (1990) on Perruchet and Pacteau (1990), the authors argue further against the claim that subjects, given a set of gramatical strings, implicitly abstract their constituent rules. On the one hand, the fragmentary knowledge of bigrams and trigrams, which accounts for performance on standard tests of grammaticality, may be formally described as abstract but can hardly be conceived of as the end product of active abstraction. On the other hand, transfer tasks may reveal some genuine abstraction process. Evidence for the implicitness of this process, however, is highly debatable. Incidental instructions are not a reliable guarantee of automaticity of abstraction in the study phase. Still more damaging to the views of Reber and Mathews is that abstraction may occur during the transfer phase while subjects are engaged in explicit cognitive activities.

In a recent article (Perruchet & Pacteau, 1990), we reported a set of experiments challenging the widely accepted inference that subjects' above-chance performance in artificial grammar learning settings testifies to the unconscious abstraction of grammatical rules. Most of the commentaries that Reber (1990) and, to a lesser extent, Mathews (1990) addressed to this article concern proposals that are in fact overgeneralizations of our original claims. We first deal briefly with what we feel to be misinterpretations of our position, so we may locate and discuss more thoroughly the specific area of disagreements.

Reber's (1990) rendition of our position was that "explicit and overt cognitive functions, specifically those typically assigned to consciousness, take precedence over other forms of mentation" (p. 341). Arguing against this so-called "consciousness stance," he mentioned a number of phenomena in which conscious and unconscious processes may be dissociated (in particular in the areas of frequence encoding, subliminal perception, priming, and implicit memory). He then (a) presented neuropathological data showing that nonconscious processes are far less affected by disease and injury than controlled and effortful processes and (b) emphasized the longer evolutionary history of implicit systems. Reber believed that all this supports the "primacy of the implicity." Mathews (1990) echoed this perspective, although in a far more restricted area, when he stated that the rules subjects extract from grammatical items need an unconscious integrator to result in effective grammaticality judgments.

We have no quarrel with the contention that cognitive activities may be partitioned into conscious and unconscious processes and, furthermore, that unconscious processes are of primary importance in various adaptive situations, such as those alluded to by Reber (1990) and by Mathews (1990). In this sense, we agree with Reber on the "primacy of the implicit."[1]

This does not, however, imply that all types of processes can operate unconsciously. The processes under scrutiny in our article (Perruchet & Pacteau, 1990) were those that underlie the acquisition of abstract knowledge. We argue here that the Reber (1990) and Mathews (1990) comments fail to provide compelling arguments to support the view we challenged, namely, that subjects given a set of grammatical strings abstract their constituent rules in an implicit mode.

On Abstraction

Our experiments involved an artificial grammar situation that reproduced most of the characteristics of the situations used in prior studies. For instance, the grammar itself and the duration of the study phase were identical or closely similar to the ones Reber and Allen (1978) or Reber, Kassin, Lewis, and Cantor (1980) used. We showed that subjects' grammaticality judgments, which were taken as evidence for unconscious abstraction in these studies, could be accounted for by the fragmentary knowledge of the pairs of consecutive letters composing the items, in addition to knowledge pertaining to the first and last permissible letters. We concluded that grammaticality judgments obtained in standard situations may be accounted for by surprisingly simple pieces of knowledge.

In their comments, Reber (1990) and Mathews (1990) criticized neither the empirical validity of these findings nor the conclusion we drew from them. Rather, Mathews questioned its generalizability, arguing that other forms of knowledge are revealed when (a) more propitious study conditions

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[1] Reber (1990) pitted his claim for the "primacy of the implicit" against our claim for the "primacy of declarative over procedural knowledge" (Perruchet & Pacteau, 1990, p. 273). However, there is no real contradiction. It is obvious that in our article, "primacy" referred to the precedence in time in the learning course and not to functional supremacy in ordinary situations.

are designed and (b) tests other than the standard ones are used. Both points are examined in turn.

Is Knowledge Acquired in More Propitious Study Conditions Abstract?

Mathews (1990) argued that subjects acquire richer and more abstract knowledge when a more complex grammar and a longer study phase are used. We obviously agree that the richness of knowledge acquired in artificial grammar learning settings depends on the specificities of the design. However, the claim that additional knowledge acquired in the most favorable conditions is abstract in nature warrants examination.

According to Reber and Lewis (1977) and Mathews et al. (1989), who investigated the knowledge acquired in extended training sessions through various methods, subjects essentially acquired knowledge pertaining to valid bigrams and trigrams along with their spatial position in the strings (see also Dulany, Carlson, & Dewey, 1984). We argue below that this information is not abstract in any psychologically meaningful way.

According to Mathews (1990), a rule is abstract when it enables identification of more than one position in a search space. For instance, the rule "a grammatical string may begin with CVC" is abstract inasmuch as it makes it possible to identify several strings from the whole set of items consisting of all the possible combinations of allowable letters. This formal definition of abstractness has received a large consensus from early writings in philosophy to modern-day artificial intelligence. In our view, however, this definition has only partial relevance, because it must also be shown that this knowledge is the final outcome of an abstraction process (i.e., one which results from analytical operations performed to extract componential information from the whole string as a single entity). If it can be shown that subjects primarily encode fragmentary information, it seems psychologically irrelevant to refer to abstraction to account for the availability of this information during testing.

Although direct evidence on this issue is lacking, it appears unlikely that subjects cope with new strings of consonants as integrated units. This is true even for pronounceable pseudowords that have a priori stronger cohesiveness than strings of consonants. Hock, Malcus, and Hasher (1986) showed convincingly that this type of stimulus is encoded in memory at the letter level. On more speculative grounds, it must be noted that letters do not constitute integral dimensions of the items (e.g., Lockhead, 1972), which would favor holistic apprehension of the stimulus. Letters are separable and, moreover, separate (Shepp, 1989) dimensions of items. The knowledge that can be qualified as abstract in a formal sense may result from a failure to integrate or unify the components of the displayed strings, rather than from an active process of feature extraction from a primarily unitary representation.

Is the Knowledge Revealed in Transfer Tasks Abstract?

Thus far, we have examined only evidence for abstract knowledge obtained in conventional grammaticality tests, in which test items are generated by the same grammar as the one generating study items. In their studies, Mathews et al. (1989) and Reber (1969) asked for grammaticality judgments about strings generated by a grammar that was structurally identical to the one used in a study phase but instantiated with a different letter set. Although performance in this transfer task was considerably poorer with regard to performance on standard tests, it remained significantly better than chance.

According to Mathews (1990), this ability to generalize from the initial search space to a new one constitutes a second way of defining and testifying to abstraction. We acknowledge that transfer is difficult to account for unless it is assumed that subjects actually abstract from the specific stimulus array. Subjects do not deal exclusively with concrete fragments of displayed material but rather must identify properties shared by several physically different stimuli, which implies a shift in the level of analysis. Another indication that subjects are able to perform such cognitive operations is that they can verbalize rules that are not restricted to specific material, such as rules concerning the location of the runs of identical letters within the strings (Mathews, 1990).

Although we did not tackle transfer tasks in our original article, evidence for abstraction on these tasks does not conflict with our position. We do not question human abstraction ability, no more than we question the existence of unconscious processes. What we do question is the joint possibility of unconscious abstraction. The issue discussed below is to determine whether evidence for abstraction observed in transfer tasks indeed reflects implicit processes.

On Implicitness

In the context of artificial grammar learning, the term *implicit* is used in two different ways. *Implicit* can refer to the learning process. In this case it is virtually synonymous with *automatic*, as used in the context of frequency coding (Hasher & Zacks, 1979; in most other areas of research, automaticity is the end product of intensive practice). A process is said to be implicit or automatic when it requires few or no attentional resources and is out of intentional control. Second, *implicit* refers to the resultant memorial representations. In this case it is synonymous with *unconscious*. There is an evident need to differentiate these meanings. Acquisition may be effortful and intentional and the resulting knowledge unconscious, for instance, as a consequence of intensive practice; conversely, it is conceivable that an automatic mode of acquisition may generate knowledge that is available to conscious thought. This leads us to dealing with two questions: (a) Is abstraction performed automatically (i.e., without effort or intention)? (b) Is abstract knowledge unconsciously represented?

From Incidental Instructions to Implicit Learning

To make learning of artificial grammar implicit, subjects are given so-called implicit instructions at the start of the study phase. For the sake of clarity, we prefer to use the term *incidental* (vs. *intentional*) instead of *implicit* (vs. *explicit*) to designate experimental conditions, in keeping with a long-standing tradition in the psychology of learning and memory. That implicit learning follows from incidental instructions is a tacit assumption. The issue at hand is whether incidental instructions are sufficient to ensure implicitness or automaticity of learning.

Typically, subjects are asked to learn the displayed items by rote, with no information on their rule-based structure. In our opinion, this practice may prompt subjects to adopt a mnemonic strategy consisting, precisely, of searching for the rules. In fact, discovering an abstract rule, such as "letter repetitions never occur at the beginning of the strings," may be very helpful in memorizing strings of consonants. The frequent finding that grammaticality judgments of subjects receiving incidental or intentional instructions do not differ significantly (e.g., Dulany et al., 1984; Mathews et al., 1989; Perruchet & Pacteau, 1990; see Reber et al., 1980, for an exception) lends weight to this view. Surprisingly, this interpretation is never mentioned, and the lack of empirical differences between incidentally and intentionally instructed subjects is assumed to be due to the fact that intentional instructions have no effect on performance, either positive or negative.

Further work will be needed to warrant the inference that incidental instructions induce implicit processing. The effect of a variety of orienting tasks should be investigated systematically. (Mathews et al., 1989, Experiments 3 and 4, and McAndrews & Moscovitch, 1985, constitute interesting steps in this direction.) But, above all, the automaticity of processing occurring in the study phase should be assessed by methods that have been devised for this purpose in contemporary cognitive psychology. It is especially surprising that claims for implicitness of artificial grammar learning have been made for more than 20 years without any empirical support from dual-task experiments.

Abstraction May be Postponed Until the Transfer Phase

Throughout this discussion, we have tacitly assumed that the abstract knowledge revealed in transfer tasks is elaborated during the study phase. Alternatively, however, subjects may simply encode specific items during the study phase, store them in memory, and perform abstractive operations on their reminded representations in the presence of new transfer items. For example, subjects asked for a grammaticality judgment about DJDMJJ in the transfer phase may retrieve study items such as CVCPVV, SCPTVV, and so on, and then abstract a common feature: Repetitions of letters occur at the end of the items in all cases. This alternative bears on the distinction between early and late computation models of categorization (Estes, 1986). Although early computation models, in which full analysis of study exemplars takes place in the encoding phase, are implicit in traditional frameworks, there is a growing body of evidence for the late, or "in line" (Smith, 1989), computation model, in which at least some processing occurs while subjects are dealing with new stimuli (e.g., Brooks, 1990; Medin & Ross, 1990).

This alternative is obviously of crucial importance to the issue at hand. If researchers aim at eliciting implicit processing in the study phase (although unsatisfactorily, as stressed above), they have never controlled the nature of the processing occurring in the test phase. Typically, subjects at the beginning of the test phase are informed that the study strings were generated by a complex set of rules and that they should now assess the well-formedness of new items with regard to these rules. These instructions inevitably shift subjects to a rule discovery mental set. Mathews et al. (1989) did not mention the rule-based structure of items, but their test procedure remained explicit in nature insofar as their subjects were instructed to make direct comparison between the study and test items.[2] Thus, clear evidence for a model in which abstraction is performed during the transfer task would be highly damaging to the claim that performance in artificial grammar settings testifies to implicit abstraction.

The recent Mathews et al. (1989) experiments were not designed to tackle this issue but nevertheless provided data suggesting that at least some rules are abstracted in the transfer phase. For instance, above-chance grammaticality judgments for items made up of new letters did not appear immediately after letter change but rather after some feedback trials. This result is consonant with the idea that subjects do not generate ready-to-use abstract rules in study phase but rather build them when given a problem that prompts rule elaboration. In the same vein, abstract verbalization was apparently—the Mathews et al. (1989) article is not entirely clear on this point—produced only on request in the instructions.

Is Rule Knowledge Unconsciously Represented?

We turn now to the second issue raised by implicitness, which pertains to the unconscious nature of acquired knowledge. To date, there is converging evidence that fragmentary specific knowledge—on valid bigrams or trigrams, for instance—is available to consciousness. Moreover, Dulany et al. (1984), Druhan and Mathews (1989), and Perruchet and Pacteau (1990) have demonstrated in a variety of methods of investigation that conscious specific knowledge is sufficient to account for grammaticality judgments.

The criticism that Reber (1990) addressed to our study does not seem to invalidate these conclusions. Reber (1990) pointed out that our experimental conditions (especially the simultaneous presentation of the whole set of items from printed booklets in the study phase) favor conscious, hypothesis-testing behavior, as compared with the more typical trial-by-trial procedure. Although Reber (1990) may in the end be right, we note that (a) he himself has used this mode of presentation in studies inferring implicitness of learning (e.g., Reber et al., 1980); (b) the only study we are aware of that directly compared simultaneous and sequential modes of presentation (Dulany et al., 1984) reported no significant differences; and (c) the above-mentioned studies, whose re-

[2] The meanings of the terms *implicit* and *explicit* differ when they are associated with learning (as here) or memory (Schacter, 1987). By and large, the terms refer to the study phase in the former case and to the test phase in the latter. What is implicit in an implicit memory test is the relationship between the test and the initial event. The grammaticality judgments subjects are asked to make in the artificial grammar paradigm constitute an explicit task in this regard, because subjects are explicitly informed that the grammaticality of test strings must be assessed with respect to the characteristics of the study strings.

sults are congruent with ours, used a trial-by-trial mode of presentation.

Reber (1990) also stated that in our simulation of grammaticality judgments, which used the knowledge of bigrams as data base, we chose the criteria for discriminating recognized from unrecognized bigrams to optimize the fit between simulated and observed performances. Recall that subjects were asked to rate how well they recognized individual bigrams on a 6-point scale. This procedure does involve determination of a cutoff point, because the simulation calls for dichotomic data. This point, however, was chosen to optimize fit between simulated and observed proportions of the items classified as grammatical and ungrammatical, whereas the score of interest pertains to solution accuracy. It is worth adding that our results would not have been trivial if determination of the cutoff point had been directly based on the solution accuracy: The fact that the quality of fit depends on the choice of a criterion does not entail that a criterion ensuring a good fit can be found in all cases, regardless of data base.

Evidence for the consciousness of abstract knowledge is sparser. The strong claim that all abstract knowledge is unconscious in nature is clearly refuted. Mathews et al. (1989) reported that subjects were able to verbalize abstract knowledge after studying strings composed of a given set of letters; when this knowledge was conveyed to a naive partner, the partner performed better than chance on a grammaticality test for strings composed of another set of letters. We, however, lack quantitative simulations to test whether this verbalizable abstract knowledge is sufficient to account for all transfer performance.

Concluding Remarks

The preceding discussion raises a number of issues that go beyond the field of artificial grammar learning. The first pertains to the empirical scope of a position challenging the occurrence of implicit abstraction. Recent works have shown that other intended demonstrations of implicit abstraction can also be reduced to a simpler form of learning (e.g., Perruchet, Gallego, & Savy, 1990; Sanderson, 1989). Further studies are needed before generalization to other laboratory settings and, furthermore, to real-world situations will be possible. Other issues are theoretical in nature. Space prevents us from dealing with more than one aspect, so we will focus on the respective role of implicit and explicit learning in adaptive processes.

We fully endorse the synergistic perspective outlined by Mathews et al. (1989), whose main assumption was that implicit and explicit learning processes may interact positively; similar views underpin part of the experimental research program of our laboratory (e.g., Lautrey, 1987). Our only point of departure concerns the functions assigned to the two modes of learning. Our position is that abstraction is associated with explicit cognitive functions, specifically those related to logical reasoning and to analytic modes of processing.

If one assumes that structural, abstract knowledge is at the core of the mind, our position then drastically minimizes the role of implicit processing in learning, which may be viewed as a somewhat embarrassing consequence. Reber (1990) may have been right in stating that a framework that assigns almost no adaptive value to unconscious acquisition processes would run counter to the basic tenets of evolutionary biology. Consciousness is a late arriver in phylogenetic and ontogenetic development, and powerful learning abilities are evidenced more precociously.

There is, however, another theoretical alternative based on the contention that a large amount of adaptive behavior derives from the acquisition and use of specific knowledge. There is growing evidence in the fields of categorization and problem solving supporting models that posit the primacy of specific knowledge over abstract structures (e.g., Brooks, 1990; Medin & Ross, 1990). Most of the data (which seemed at one time to be clear-cut support for rule, schema, or prototype abstraction) have been reinterpreted without assuming that abstractive abilities are called into play (cf. also the upsurge of connectionist models, whose relevance to this issue we outlined earlier, Perruchet & Pacteau, 1990). Hence, exempting implicit learning from any role in the acquisition of abstract knowledge should not be construed as a major limitation on its explanatory power. Rather than minimizing the role and power of implicit learning, our recent studies and work in progress aim at contributing to a reinforcement of the contention that specific knowledge predominates over abstract structures.

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