Parity effects in an implicit-learning task

André Didierjean*
University of Franche-Comté, France

Is it possible to extract knowledge from complex material and then unknowingly use it? This key question in the field of implicit learning is addressed here in three experiments using the invariant paradigm. The experiments showed that after seeing a series of items consisting of pairs of 2-digit numbers (e.g. {52; 74}) governed by a rule, subjects judged that new items that followed the rule were more familiar than ones that did not. Experiment 1 showed that this effect was observed when all bigrams seen in phase 2 were new. Experiments 2 and 3 controlled for some 'classic' biases and showed that the effect depended on what rule was at stake. An effect was observed only if the rule used brought to bear a salient categorical property in memory: parity.

Can human beings extract rules from complex material and then unknowingly use them without even being aware of what they are? Few fields in cognitive psychology have a fundamental question as controversial as this at the core of research on implicit learning. A large number of studies conducted over the past 30 years seem to show either that participants have the capacity to implicitly extract rules (e.g. Knowlton & Squire, 1996; Meulemans & Van der Linden, 1997; Reber, 1967, 1969) or, on the contrary, that they do not have this capacity (e.g. Johnstone & Shanks, 1999, 2001; Kinder & Assman, 2000; Perruchet & Pacteau, 1990; Shanks & St. John, 1994). In line with the above research, the present study was aimed at finding out whether implicit-learning effects can be obtained from a categorical property: parity.

Tasks used
Most tasks used in implicit-learning studies are based on the same principle. In the first phase, participants are given material constructed from rules they do not know. In the second phase, they have to perform a task that requires using the knowledge built during the first. The most widely used tasks of this type are ones in which the material complies with the rules of an artificial grammar. The term artificial grammar is used here to mean a set of arbitrary rules governing the order of letters in strings. In such 'classic' studies, the two experimental phases are as follows. In Phase 1, the participants are shown strings of letters that abide by the rules of the grammar. They are not informed of

* Correspondence should be addressed to Laboratoire de Psychologie, University of Franche-Comté, 30, rue Mègevand, 25030 Besançon, France (e-mail: Andre.Didierjean@univ-fcomte.fr).
how the strings were constructed and their task is either to memorize the strings (Reber, 1967, 1976) or to simply study them (Reber & Allen, 1978; Reber, Kassin, Lewis, & Cantor, 1980). In Phase 2, run immediately afterwards, the participants are told that the letter strings they just saw followed certain rules, and they are asked to state whether the items in a new series of strings follow the same rules. The typical result of this type of task is that the participants are able to judge the new strings better than by chance, but turn out to be incapable of verbalizing the rules they used to make their judgments (Reber, 1969). A similar result has also been observed in other tasks, such as serial reaction time tasks (e.g. Nissen & Bullemer, 1987; Perruchet & Amorim, 1992) and more complex interactive cognitive tasks (e.g. Berry & Broadbent, 1984; Hayes & Broadbent, 1988; Pacton, Perruchet, Fayol, & Cleeremans, 2001).

Proposed interpretations

Three major theoretical interpretations have been proposed to explain the classical results obtained on implicit-learning tasks (for a review, see Cleeremans, Destrebecqz, & Boyer, 1998).

1. Participants extract abstract knowledge and then apply it (Reber, 1969, 1989); in this view, participants are unaware of the rules they extract and use.
2. Participants memorize exemplars during the first phase and then base their judgments on the resemblance between the exemplars memorized and the target exemplars seen during the second phase (Brooks & Vokey, 1991; Vokey & Brooks, 1992).
3. Participants do not memorize exemplars in their entirety but fragments of knowledge. In artificial grammars, for example, participants may learn ‘chunks’ composed of two or three letters (Perruchet, 1994; Perruchet & Pacteau, 1990); then during the second phase, items that do not contain any familiar chunks are seen as ‘non-grammatical’. In the last two views, the participants do not have to extract rules to succeed in the task.

In most studies, awareness of the knowledge used is assessed on the basis of verbalizations collected from the participants after the experiment is over. Given that the nature of this knowledge is uncertain, the risk is that the participants will consciously apply knowledge that is different from that expressed in their verbalizations (e.g. Shanks & St. John, 1994).

Although at the present time, everyone agrees that participants memorize exemplars in this type of task, there is as much disagreement as ever about implicit-rule extraction. Some authors contend that participants also implicitly extract rules (Knowlton & Squire, 1996; Meulemans & Van der Linden, 1997; Reber, 1997), while others say that no experimental proof has yet been found showing this to be the case (Johnstone & Shanks, 1999, 2001; Redington & Chater, 1996; Shanks & St. John, 1994).

Various attempts have been made over the past few years to study implicit learning while clearly separating the rules from the exemplars, either by adapting artificial grammar tasks (Higham, Vokey, & Pritchard, 2000; Johnstone & Shanks, 2001), or by developing new tasks (e.g. Vinter & Perruchet, 1999). The present study used the ‘invariant paradigm’ (e.g. Bright & Burton, 1994; Cock, Berry, & Gaffan, 1994; McGeorge & Burton, 1990; Newell & Bright, 2002; Wright & Burton, 1995). In the first phase of this paradigm, participants are presented with material that contains
a regularity (e.g., in numerical items, the presence of the numeral 3; McGeorge & Burton, 1990). In the second phase, they perform a recognition task in which they have to recognize the items they just saw among new items. The experimental design is such that although all items in the second phase are new, half of them exhibit the same regularity as the items in the first phase and the other half do not. The results obtained using this task seemed promising, but it turned out that they could be explained without bringing implicit learning to bear, because the rule used covaried with other properties that participants could utilize (e.g., Newell & Bright, 2002; Wright & Burton, 1995).

The present study used a version of this paradigm that Wright and Whittlesea (1998) employed in a study on the active or passive nature of learning. In Wright and Whittlesea’s version, participants are given a series of two two-digit numbers to study or perform operations on, depending on the experiment. The second phase is a recognition task: for each pair of two-digit numbers shown, the participants have to state whether that item was seen in Phase 1 or whether it seems new. The principle behind these experiments is that all Phase 1 items follow the same rule. For example, in one of the experiments, the sum of the first two digits is equal to the sum of the next two (e.g., 72 63); in another, the digits in all items alternate between odd and even (e.g., 36 58). For the second phase, although all items presented are new (not seen in Phase 1), some follow the Phase 1 rule (e.g., 94 76 follows the odd–even rule) and some do not (e.g., 68 74 does not because 6 is even). Wright and Whittlesea (1998) showed that the task performed on Phase 1 affects the performance on Phase 2. When certain operations have to be performed on Phase 1, participants prefer the rule-obeying items in Phase 2. With other operations, this preference is no longer observed. As the authors themselves noted, it is difficult in their studies to determine whether the observed preference for the rule-obeying items on Phase 2 is due to implicit extraction of the Phase 1 rule, or to the presence of bigrams already encountered in the rule-obeying items. Participants were found to be sensitive to the presence of two-digit numbers already seen (Experiment 3A), but since the authors’ goal was to test the role of the operations performed on the materials, they did not control this factor.

The aim of the present study was to reapply this paradigm in an attempt to determine whether participants can be sensitive to the presence of a rule without being aware of it, when this rule is based on a categorical property. Experiment 1 recreated Wright and Whittlesea’s (1998) experiment while controlling the presence or absence of already seen bigrams. Experiment 2A used a modified version of the rule to control the frequency of the digits in the different positions of the items, and showed that the type of rule plays a critical role. Experiment 2B controlled for two common biases encountered in this type of task. Experiment 3 proposed different versions of the rule used in Experiment 2, and showed that participants can activate and then use a rule without being aware of its presence in the material when it is based on a categorical property that pre-exists in memory and is salient.

**EXPERIMENT 1**

Can Wright and Whittlesea’s (1998) result be simply explained in terms of a preference for items containing a bigram already seen in Phase 1? To answer this preliminary question, Experiment 1 was conducted using Wright and Whittlesea’s task and their odd–even alternation rule (Experiment 3), while controlling the presence or absence of already seen bigrams. In the first phase, participants had to read aloud 16 items (pairs of
two-digit numbers) with an alternating odd–even structure. In the second phase, they were supposed to try to recognize the first-phase items among 32 new items. In truth, all items in the second phase were new, but half of them had the same alternating odd–even structure. In addition, for the items that obeyed the rule as well as for those that did not, half of the items had one new bigram and one already seen bigram and the other half had two totally new bigrams. Unlike the Wright and Whittlesea study, in an attempt to prevent participants from memorizing the middle bigram (e.g. the 63 in 16 32), the two numbers in each item were separated by a semicolon (e.g. {16; 32}).

Method

Participants
Twenty-seven psychology students participated in the experiment (21 females and 6 males; mean age: 20 years and 4 months, standard deviation: 18 months).

Materials

Study phase
The items for the study phase were taken from a pool of bigrams containing digits 1–8. They were 12, 16, 32, 34, 56, 58, 74, and 78. Each bigram was combined with four other bigrams from the same pool, twice in first position and twice in second position, making 16 two-bigram items. In each item, the bigrams were separated by a semicolon (e.g. {34; 58}). A given digit never occurred twice in the same item. The 16 items are presented in Appendix A.

Test phase
Four types of items were generated. All items in this second phase were new. Half obeyed the odd–even alternation rule and half did not. In each case, half of the items contained one old bigram and the other half contained only new bigrams. These items are also presented in Appendix A.

The items that followed the odd–even alternation rule were generated from the eight study-phase bigrams and eight new odd–even bigrams made up of digits 1–8. The new bigrams were 14, 18, 36, 38, 52, 54, 72, and 76. Sixteen items were constructed from these bigrams. Eight of them were new/old items, that is, items in which one of the bigrams had been seen in Phase 1 (e.g. the item {12; 76} contains bigram 12 seen in Phase 1 and new bigram 76). For four of these items, the new bigram was in first position, and for the other four, it was in second position. They were constructed by associating each of the eight Phase 1 bigrams with one of the eight new bigrams. No digits occurred twice within an item. The other eight items were new/new items in which neither of the bigrams had been seen in Phase 1. To construct these items, each bigram in the above pool was combined with two other bigrams from the same pool, once in first position and once in second position.

The items that did not follow the odd–even alternation rule were generated from eight even–odd bigrams made up of digits 1–8. They were 25, 27, 41, 45, 63, 67, 81, and 83. Sixteen items were constructed from these bigrams. Eight were new/old items in which one of the two bigrams had been seen in Phase 1 (e.g. the item {63; 12} contains bigram 12 seen in Phase 1 and new bigram 63). In four of the eight, the new bigram was in first position, and in the other four, it was in second position. These items were generated by associating each of the eight Phase 1 bigrams with one of the eight new bigrams.
bigrams. The same digit never occurred twice within an item. The remaining eight items were new/new items containing two bigrams not seen in Phase 1. To construct these items, each bigram in the above pool was combined with two other bigrams from the same pool, once in first position and once in second position.

Procedure
The experimenter informed the participants that they were going to take part in an experiment involving pairs of two-digit numbers, which would be presented during the first phase. For this phase, they were asked to slowly read the numbers aloud, treating the items as two-digit numbers (e.g. (34; 58) was to be read ‘thirty-four; fifty-eight’). The 16 items generated for this phase were shown one by one in random order. As soon as an item appeared, the participant had to read it aloud and then press a key to display the next item.

At the end of this phase, the participants were told that they would have to try to recognize the items seen during the study phase, mixed in with as many new items. They were supposed to answer as quickly as possible and to base their answers on their feeling of familiarity for the items. The 32 items were presented one by one in random order in the middle of the screen, after the display of an asterisk.

After the test phase, the experimenter asked the participant two questions. One was whether he/she had used a ‘trick’ to decide whether an item was new. Once the answer was given, the participant was told that there were rules governing the study material and asked whether he/she had noticed any regularities.

Results
Post-task questions
When the participants were questioned after the test about their detection or non-detection of the rule governing the material, 7 of the 27 participants in the experiment said they had noticed that the Phase 1 items were all even numbers (e.g. 16; 34). Given that the aim here was to find out whether the responses of participants who did not consciously perceive the rule nevertheless exhibited sensitivity to it, these seven participants were not included in subsequent analyses.1 The other 20 participants did not mention the oddness or evenness of the items, or anything else that might explain the results. When these participants said they had noticed regularities, they referred to the fact that certain bigrams were repeated across items, as in ‘I noticed that the number in first position (e.g. 16 in 16; 34) sometimes appeared in second position in the next item’ (due to the random display order, a bigram sometimes occurred in two consecutive items, but in different positions).

Test phase
Table 1 presents the mean (false) recognition rate on the four types of items. An ANOVA was conducted with oldness/newness and rule abidance/violation as within-subject factors. There was an effect of the new/old factor, $F(1, 19) = 17.0, \text{MSE} = 0.026, p < .001$, the rule-following factor, $F(1, 19) = 116.6, \text{MSE} = 0.045, p < .001$, and an interaction between the two, $F(1, 19) = 7.3, \text{MSE} = 0.7, p < .05$. Among the items

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1 The responses of five of them showed that they systematically based their answers on the rule. They answered ‘seen’ to nearly every item containing even bigrams, and ‘not seen’ to nearly every item containing odd bigrams. The other two participants said they had noticed the rule, but their performance did not reflect this fact.
with new bigrams only, the participants clearly preferred the ones whose bigrams followed the rule, $F(1, 19) = 110.5, \text{MSE} = 0.030, p < .001$. Response time, which had also been recorded, did not differ significantly across the different types of items.

**Table 1.** Mean (false) recognition rate, according to whether the items followed or violated the rule, and whether they contained new or old bigrams

<table>
<thead>
<tr>
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<th>New/old items</th>
<th>New/new items</th>
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<tbody>
<tr>
<td>Rule-following</td>
<td>.76 ($SD = 0.14$)</td>
<td>.67 ($SD = 0.24$)</td>
</tr>
<tr>
<td>Rule-violating</td>
<td>.31 ($SD = 0.16$)</td>
<td>.09 ($SD = 0.16$)</td>
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**Discussion**

The aim of Experiment 1 was to control the occurrence of already seen bigrams, in an attempt to find out whether the effect observed by Wright and Whittlesea (1998) could be explained simply by the presence of these bigrams. The results showed that this factor alone cannot account for their results. Indeed, while participants exhibited a preference for items containing bigrams they had already seen, they also manifested a clear-cut preference for items that obeyed the odd–even alternation rule. However, while all of the bigrams in Phase 2 were new, the type of rule used here makes it impossible to control the frequency of occurrence of the digits in each position (e.g. an odd–even item necessarily starts with 1, 3, 5, 7, or 9 and necessarily ends with 2, 4, 6, or 8). In Experiment 2A, two modified versions of the rule were used to control the frequency of the different digits.

**EXPERIMENT 2A**

The odd–even alternation rule is such that to follow or not follow the rule, one necessarily uses certain digits in certain positions. That is, abiding by the rule necessarily means having 2, 4, 6, or 8 and not 1, 3, 5, 7, or 9 in the second position of each bigram. The purpose of Experiment 2A was to test for participant sensitivity to a rule that no longer required specific digits in specific positions. For the first group, called the ‘alternation-rule’ group, a modified version of the odd–even alternation rule was devised where only alternation between oddness and evenness was at stake, and either type of digit could come first. Thus, items that abided by the rule could be (odd–even; odd–even) (e.g. (38; 56)) or (even–odd; even–odd) (e.g. (63; 25)). In the study phase of the experiment, participants saw items that obeyed this rule. Half of the items were (odd–even; odd–even) and half were (even–odd; even–odd). In the second phase, as in Experiment 1, the participants had to decide whether or not each item in the new series had already been seen. Half of the new items followed the rule ((odd–even; odd–even) items and (even–odd; even–odd) items) and half did not ((odd–even; even–odd) items and (even–odd; odd–even) items). The rule-violating items were generated by pairing two bigrams that obeyed the rule. For example, items (89; 23) and (76; 14), both of which follow the rule, were used to construct items (76; 23) and (89; 14), which do not. In this way, all Phase 2 items were new, and among the bigrams that obeyed the alternation rule and those that did not, all digits appeared exactly the same number of times in the same position.

A second group, called the ‘complex-alternation-rule’ group, studied eight (odd–even; even–odd) items and eight (even–odd; odd–even) items on the first phase,
and then underwent exactly the same second phase as the first group. The purpose of having the second group was to find out whether participants could be sensitive to a more complex rule than simple odd–even alternation. For these participants, the (odd-even; odd-even) and (even-odd; even-odd) items in the second phase were the rule-violating items and the (even-odd; odd-even) and (odd-even; even-odd) items were the rule-following items.

Method

Participants
Forty psychology students participated in the experiment (34 females and 6 males; mean age: 19 years and 3 months, standard deviation: 5 months).

Material

Study phase
For the alternation-rule group, the material for the first phase consisted of the eight items from Phase 1 of Experiment 1, which combined bigrams 12, 16, 32, 34, 56, 58, 74, and 78 in such a way that each bigram occurred once in first position and once in second position, and the eight (even-odd; even-odd) items from Phase 2 of Experiment 1, which combined bigrams 25, 27, 41, 45, 63, 67, 81, and 83 in such a way that each bigram occurred once in first position and once in second position.

For the complex-alternation-rule group, the material for the first phase consisted of eight (odd-even; even-odd) items and eight (even-odd; odd-even) items generated by pairing one of the bigrams 12, 16, 32, 34, 56, 58, 74, and 78 with one of the bigrams 25, 27, 41, 45, 63, 67, 81, and 83 in such a way that each bigram occurred once in first position and once in second position.

The entire set of items is presented in Appendix B.

Test phase
Two types of items were generated, 16 that obeyed the odd-even alternation rule and 16 that did not (these items are also presented in Appendix 2). All of the bigrams were new. The odd-even-alternation rule-following items were of two types: eight were (odd-even; odd-even) and eight were (even-odd; even-odd). The first eight were the new/new (odd-even; odd-even) items used in Phase 2 of Experiment 1, and the remaining eight were constructed from the bigram pool 23, 29, 43, 47, 61, 65, 87, and 89. Each bigram was combined with two other bigrams from the same pool, once in first position and once in second position. No digits occurred twice in the same item. The 16 odd-even-alternation rule-violating items were generated from the bigrams in the alternation rule-following items by systematically associating an odd-even bigram with an even-odd bigram. Combining the eight (odd-even; odd-even) items with the eight (even-odd; even-odd) items gave eight (odd-even; even-odd) items and eight (even-odd; odd-even) items. No digits were repeated within a given item.

Procedure
The procedure was the same as in Experiment 1.
Results

Post-task questions
None of the 40 participants’ answers to the two questions indicated that they were aware of the rule used. The only regularity mentioned was the repetition of certain bigrams in different Phase 1 items (each bigram had in fact appeared twice in two different items).

Test phase
An ANOVA was conducted with item acceptance rate as the dependent variable, group (alternation rule vs. complex-alternation rule) as a between-subject factor, and type of item (followed vs. violated the rule used in Phase 1) as a within-subject factor. There was a group effect, $F(1, 38) = 16.71$, MSE = 0.42, $p < .001$, and a rule effect $F(1, 38) = 4.65$, MSE = 0.23, $p < .05$, but no interaction between the two, $F(1, 38) = 1.72$, MSE = 0.03, $p = .20$. The rule effect was observed for the alternation-rule group, $F(1, 38) = 8.20$, MSE = 0.02, $p < .01$, but not for the complex-alternation-rule group, $F(1, 38) < 1$. Although there was an overall rule effect in the alternation-rule group, the results for each rule component (odd–even; odd–even) and (even–odd; even–odd) were very different. Figure 1 shows the false recognition rate for the two groups in Experiment 2A.

For the alternation-rule group alone, the participants recognized significantly more (odd–even; odd–even) items than other items, $F(1, 38) = 23.65$, MSE = 0.29, $p < .001$.

Discussion

The main finding of Experiment 2A was the effect observed in the alternation-rule group. Although an overall effect was obtained for these participants, it can be accounted for solely by one of the two components of the rule: the items composed of two even numbers (odd–even; odd–even). These items were ‘recognized’ more often than the other items. This result points out an obvious limitation in the scope of these results. The effect observed in the alternation-rule group participants was due to a specific feature of the rule, evenness. This categorical property is known to be particularly salient in memory (e.g. Dehaene, Bossini, & Giraux, 1993; Hines, 1990; Krueger, 1986; Krueger & Halford, 1986; Shepard, Kilpatrick, & Cunningham, 1974).

Traditionally, two types of experimental bias have been proposed to account for results that seem to demonstrate the existence of implicit-learning mechanisms.

Figure 1. False recognition rate for the four types of items and the two groups in Experiments 2A and 2B. Error bars are standard errors.
The results could be due to regularities that covary with the rule used, which participants detect and consciously utilize (e.g. Churchill & Gilmore, 1998; Newell & Bright, 2002; Wright & Burton, 1995). The same results could be replicated without a learning phase (e.g. Dienes & Altman, 1997; Dulany, Carlson, & Dewey, 1984; Redington & Chater, 1996); for example, participants may think items composed of two even numbers are more familiar even though there was no learning phase. Experiment 2B was aimed at making sure that the results obtained in Experiment 2A could not be explained by either of these biases.

EXPERIMENT 2B

The purpose of this experiment was to perform two experimental controls on the results of Experiment 2A. First, Experiment 2A showed that participants who saw numbers based on an odd–even alternation rule in Phase 1 (odd–even; odd–even) and (even–odd; even–odd) later said that items composed of even numbers (odd–even; odd–even) were more familiar than the other three types of items presented. In Experiment 2B, the idea was to make sure that participants do not consider items composed of even numbers to be more familiar even without a preliminary learning phase (e.g. Dienes & Altman, 1997; Dulany et al., 1984; Redington & Chater, 1996). This was done by having one group of participants, called the ‘subliminal-priming’ group, undergo a false priming procedure. During the first phase, these participants had to read 16 words displayed one at a time on the screen after a string of £’s presented for 50 ms. After this phase, they were informed that before each word they had just read, two numbers separated by a semicolon had been displayed very rapidly (subliminally). Then, they were asked to judge the familiarity of the 32 items presented in Experiment 2A. If the results of Experiment 2A are due to a preference for even items, then participants should think that these unseen even items are more familiar.

The second aim of this experiment was to supply new experimental support for the ‘implicitness’ of the learning observed here. In the past, it has been shown that the results of implicit-learning tasks, particularly ones using the invariant paradigm, could be explained by the participants’ sensitivity to certain regularities that covaried with the rule being manipulated (e.g. Churchill & Gilmore, 1998; Newell & Bright, 2002; Wright & Burton, 1995). In this experiment, a second group of participants, called the ‘regularity-judgment’ group, saw exactly the same material as the alternation-rule group in Experiment 2A, but with different instructions. After Phase 1, the participants in this group were informed of the existence of regularities in the numbers just seen. Their task on the second phase was no longer to judge the familiarity of items but to say whether the items abided by the rules used in the first phase. If the participants had consciously noticed certain regularities in Phase 1, then they should use those regularities to perform the Phase 2 task. That is, if they noticed that the items presented followed an even–odd alternation rule or exhibited some other regularity that covaried with such a rule, then they should use that regularity to judge the items in Phase 2, for example, by rejecting items that do not obey the even–odd alternation rule.

Method

Participants

Forty psychology students participated in the experiment (36 females and 4 males; mean age: 19 years and 5 months, standard deviation: 17 months).
Material
For the regularity-judgment group, the material in both phases was the same as for the alternation-rule group in Experiment 2A. For the subliminal-priming group, the Phase 1 material consisted of 16 common words; the Phase 2 material was the same as in Experiment 2A.

Procedure

Regularity-judgment group
The participants in this group underwent Phase 1 exactly as the participants in Experiment 2A. On this phase, they read aloud 16 items composed of two two-digit numbers separated by a semicolon (({odd–even; odd–even} and {even–odd; even–odd}). Then the experimenter told the participant:

‘The material you just read was constructed according to certain rules. You are now going to see some new numbers, half of which follow the same rules and half of which break those rules. Your task will be to decide whether each pair of numbers displayed on the screen seems to follow the rules or seems to break them.’

Subliminal-priming group
During the first phase, the participants in this group had to read aloud 16 common words displayed one at a time on the screen. Each word was preceded by an asterisk and then a string of £’s displayed for 50 ms. After this phase, the experimenter told the participant:

‘As you may have noticed, each word you just read was preceded by two 2-digit numbers presented very rapidly (subliminally). You are now going to see the number pairs you just saw subliminally for a longer time, but mixed in with as many new pairs of numbers. Your task will be to try to identify the items you already saw. Naturally, you’ll find this task difficult because the numbers you saw were displayed for so short a time that you were not conscious of their presentation. So, you should let your intuitions guide you and answer according to any feeling of familiarity you might have for certain items.’

Results
Figure 2 shows the false recognition rate for the two groups in Experiment 2B. An ANOVA was conducted with item-acceptance rate as the dependent variable, group (subliminal priming vs. regularity judgment) as a between-subject factor, and type of item as a within-subject factor. There was no group effect, $F(1, 38) = 1.88$, $MSE = 0.038$, $p = .18$, no item effect, $F(3, 114) < 1$, and no interaction between the two, $F(3, 114) < 1$.

Discussion
The results of Experiment 2B showed firstly that the parity effect observed in Experiment 2A was a learning effect. When even numbers were not shown in Phase 1, the participants in the subliminal-priming group exhibited no preference for the even

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2 The alternation-rule group in Experiment 2A (for the {odd–even; odd–even} items) significantly outperformed the subliminal-priming group in Experiment 2B.
numbers presented in Phase 2. In addition, this experiment supplied a second experimental argument in support of the ‘implicitness’ of the learning observed here. When participants were no longer asked to judge the familiarity of the new items, but had to decide whether or not they abided by the regularity rules used in Phase 1, the parity effect disappeared. These results suggest that the effect observed in Experiment 2A was in fact caused by implicit reliance on a rule governing the material studied. Note that the task we used here to determine the implicitness of the observed effect (a conclusion that one can draw if subjects fail on this task) is precisely the task for which success has been interpreted as indicating implicit learning in most articles on implicit learning. Experiment 3 was aimed at replicating and extending this result by varying the respective proportions of {odd–even; odd–even} and {even–odd; even–odd} items in Phase 1.

EXPERIMENT 3

In Experiment 2A, the alternation-rule group participants studied eight items that contained two even numbers ({odd–even; odd–even}) and eight items that contained two odd numbers ({even–odd; even–odd}) during the first phase. Equal proportions were chosen because this made it possible to control the presence of the digits in each position. The results of that experiment showed that participants were sensitive to a rule governing only half of the items studied: the evenness of the two numbers in a given item. In Experiment 3, the proportion of {even–odd; even–odd} items and {odd–even; odd–even} items in Phase 1 was varied in a systematic way. The aim was to replicate and extend the results of Experiment 2A. If participants are sensitive to evenness more than to oddness when they study eight {odd–even; odd–even} items mixed with eight {even–odd; even–odd} items, how low can the proportion of {odd–even; odd–even} items go before the effect disappears? In this experiment, participants were divided into seven experimental groups that differed by the ratio of {odd–even; odd–even} items to {even–odd; even–odd} items in the first phase (see Appendix C for an overall view of the experimental device).

Method

Participants

One hundred and fifty-four psychology students participated in the experiment (113 females and 41 males; mean age: 19 years and 8 months, standard deviation: 21 months).

Material

Study phase

The participants were randomly assigned to seven experimental groups. A different ratio of {odd–even; odd–even} items to {even–odd; even–odd} items was given to each group on the study phase. For all groups, the materials were generated from the bigrams used in Experiment 2A. The {odd–even} bigrams used to generate the material were 12, 16, 32, 34, 56, 58, 74, and 78; the {even–odd} bigrams used were 25, 27, 41, 45, 63, 67, 81, and 83. These bigrams were combined to form {odd–even; odd–even} items and {even–odd; even–odd} items. Group 1 had 11 {odd–even; odd–even} items and 5 {even–odd; even–odd} items; Group 2 had ten {odd–even; odd–even} items and six {even–odd; even–odd} items; Group 3 had nine {odd–even; odd–even} items and seven {even–odd; even–odd} items; Group 4 had eight {odd–even; odd–even} items and eight {even–odd; even–odd}
items; Group 5 had seven (odd–even; odd–even) items and nine (even–odd; even–odd) items; Group 6 had six (odd–even; odd–even) items and ten (even–odd; even–odd) items; and Group 7 had 5 (odd–even; odd–even) items and 11 (even–odd; even–odd) items. The entire set of items is presented in Appendix C.

Test phase
The same items as in Experiment 2 were used.

Procedure
The procedure was the same as in Experiments 1 and 2A.

Results and discussion
Post-task questions
When the participants were questioned after the test about their detection or non-detection of the rule governing the material, 14 of the 154 participants in the experiment (from Groups 1, 2, and 7 only) mentioned evenness or oddness. These participants were not included in subsequent analyses.

Test phase
Figure 2 shows the ‘false’ recognition rate for the participants in the seven groups (20 participants per group) on the different types of items.

Figure 2. False recognition rate for the four types of items and the seven groups. Error bars are standard errors.
An ANOVA was conducted with item acceptance rate as the dependent variable, group as a between-subject factor, and type of item as a within-subject factor. There was an item effect, $F(3, 399) = 19.0, \text{MSE} = 0.028, p < .001$, no group effect, $F(6, 133) < 1$, and a group by item interaction, $F(18, 399) = 2.9, \text{MSE} = 0.028, p < .001$.

Several points can be noted here. First of all, the result obtained in Experiment 2A was replicated for Groups 1–6. For these groups, the false recognition rate was higher for (odd–even; odd–even) items than for (odd–even; even–odd) and (even–odd; odd–even) items, $F(1, 133) = 17.76, \text{MSE} = 0.025, p < .001$. This finding confirms the salience of evenness obtained above in Experiment 2, since it was observed even when the ratio of even-number items (odd–even; odd–even) to odd-number items (even–odd; even–odd)) was as low as 6–10 (Group 6). In addition, for Groups 1–3 (where the study materials had a large majority of (odd–even; odd–even) items), there was a high rejection rate on (even–odd; even–odd) items. They were recognized significantly less than (odd–even; even–odd) items, $F(1, 133) = 25.96, \text{MSE} = 0.025, p < .001$. This result is no doubt due to the fact that the evenness effect was so great in these two groups that it caused items with a single even bigram to still seem more familiar.

Finally, for Group 7 participants (who studied 5 (odd–even; odd–even) items and 11 (even–odd; even–odd) items), the effect observed for the other groups was reversed: these participants recognized more items composed of two odd numbers (even–odd; even–odd) than ones composed of two even numbers (odd–even; odd–even), $F(1, 133) = 5.37, \text{MSE} = 0.032, p < .05$.

**GENERAL DISCUSSION**

The overall purpose of this study was in fact quite similar to that of most studies on implicit learning: to determine whether participants can extract and use knowledge without becoming aware of that knowledge (Reber, 1989). In our study, we tested for the effect of a particular type of knowledge, namely categorical (here, parity).

The results of Experiment 1 showed that participants who saw a series of items, all of which followed the same construction rule, subsequently found new items that obeyed that rule more familiar than new items that violated it. In Experiment 2A, where the frequency of occurrence of the digits in the different positions of the items was controlled, the participants were still sensitive to the presence of a rule. However, this result was only obtained if the rule used relied on a salient categorical property in memory: evenness. Experiment 2B showed that this result was indeed learning related and was not due to the participants’ utilization of a property in the material that covaried with the rule. The regularity-judgment group participants’ failure in this experiment provides an additional argument for implicit learning, which is important here since the argument that subjects are unable to verbalize a rule must be interpreted with caution (e.g. Shanks & St. John, 1994). Experiment 3 confirmed the result of Experiment 2A, and indicated a high degree of asymmetry between sensitivity to evenness and sensitivity to oddness.

Since Reber’s (1969) first studies on implicit learning, there have been two opposing points of view. According to the first, defended by Reber (1989) himself, participants can extract an abstract rule from complex materials and then use it without knowing they are doing so. Conversely, many other authors explain the results obtained on implicit-learning tasks in terms of the participants’ sensitivity to exemplars or parts of exemplars that illustrate the rule (e.g. Johnstone & Shanks, 1999; Perruchet, 1994; Shanks & St. John, 1994). In this theoretical debate, our results show that participants...
can be sensitive to a particular property of the material: a salient categorical property in memory, evenness. This learning effect was limited to a knowledge involving a salient property that already existed in the participants’ memory. This type of effect is probably quite different from one involving complex rules that participants might learn implicitly through passive exposure to the material.

References


Received 14 February 2006; revised version received 17 September 2006
Appendix A: Material for Experiment 1

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Appendix B: Material for Experiment 2A

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### Appendix C: Material for Experiment 3

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