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The relationship between the structural mere exposure effect and the implicit learning process

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Three experiments are reported that investigate the relationship between the structural mere exposure effect (SMEE) and implicit learning in an artificial grammar task. Subjects were presented with stimuli generated from a finite-state grammar and were asked to memorize them. In a subsequent test phase subjects were required first to rate how much they liked novel items, and second whether or not they thought items conformed to the rules of the grammar. A small but consistent effect of grammaticality was found on subjects' liking ratings (a "structural mere exposure effect") in all three experiments, but only when encoding and testing conditions were consistent. A change in the surface representation of stimuli between encoding and test (Experiment 1), memorizing fragments of items and being tested on whole items (Experiment 2), and a mismatch of processing operations between encoding and test (Experiment 3) all removed the SMEE. In contrast, the effect of grammaticality on rule judgements remained intact in the face of all three manipulations. It is suggested that rule judgements reflect attempts to explicitly recall information about training items, whereas the SMEE can be explained in terms of an attribution of processing fluency.

A large part of the debate surrounding implicit learning centres on the interpretation of experimental techniques as reflecting either implicit or explicit processes (e.g., Berry, 1996; Shanks & St. John, 1994). Implicit processes are typically defined as passive, unintentional, and occurring in the absence of awareness. In contrast, explicit processes reflect intentional, active strategies accompanied by awareness (e.g., Gomez, 1997; Reber, 1989).

The most extensively researched experimental technique is the artificial grammar paradigm (e.g., Dienes, Broadbent, & Berry, 1991; Gomez & Schvaneveldt, 1994; Reber, 1967, 1976). In a standard artificial grammar experiment subjects are asked to memorize a series of consonant strings generated by a finite-state grammar. After memorization, they are told that

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all the strings were formed by a complex set of rules. In a subsequent test phase subjects are asked to classify novel strings as either conforming to these rules (grammatical) or violating them (non-grammatical). The reliable finding is that subjects perform at above-chance levels on these judgements of grammaticality, in spite of an apparent absence of declarative knowledge about the rules of the grammar. These findings have been taken as evidence that subjects unconsciously apply implicitly acquired knowledge of the grammar (Reber, 1989, 1993).

This conclusion has been challenged by a number of researchers who claim that some explicit processing is involved in the judgements of grammaticality (e.g., Dienes et al., 1991; Dulany, Carlson, & Dewey, 1984; Perruchet & Pacteau, 1990). A considerable problem in interpreting the standard judgements of grammaticality as reflecting implicit processes is that the judgements are direct rather than indirect measures of knowledge (Richardson-Klavehn & Bjork, 1988). Before making their test decisions subjects are informed of the crucial relationship between training and test items—the existence of the grammar. Thus, though subjects may not engage in explicit rule-searching strategies during training, after hearing the pre-test instructions they may do this during the test (Buchner, 1994).[1] Evidence for this explicit processing comes from a number of studies that have demonstrated that subjects do possess fragmentary explicit knowledge of features of the strings that make them either grammatical or non-grammatical (Dienes et al., 1991; Dulany et al., 1984; Gomez & Schvaneveldt, 1994; Perruchet & Pacteau, 1990). Thus, it seems that the standard rule judgements of grammaticality involve a degree of explicit processing, independent of whether or not the initial acquisition of knowledge was implicit. The potential influence of explicit knowledge limits the use of the standard direct rule judgements for providing evidence of implicit cognition in artificial grammar learning (Buchner, 1994).

One way of overcoming the problem of explicit contamination is to attempt to use indirect tests of acquired knowledge—that is, those that do not make specific reference to previously encountered instances. The advantage of indirect measures is that they are more likely to satisfy the criteria for being a test of implicit cognition because they do not encourage subjects to use conscious recollection strategies when performing classification tasks. It has been argued (e.g., Reingold & Merikle, 1988) that the best evidence for implicit processing is for an indirect measure to show a greater sensitivity to task-relevant knowledge than a comparable direct measure. This is because with all other factors being equal, subjects should be more able to apply consciously accessible knowledge when instructed to do so than when they are not required directly to apply it. Though this approach has been used to provide evidence of unconscious learning effects in a sequence-learning task (Jimenez, Mendez, & Cleeremans, 1996) (though see Shanks & Johnstone, 1999, for an alternative explanation of this result) there are no findings from the artificial grammar task suggesting that an indirect measure is *more* sensitive than a direct measure. However, some studies do claim to show direct and indirect measures with an *equal* sensitivity to grammar knowledge. These studies are important because they appear to demonstrate that subjects can apply grammatical knowledge when they are not instructed to as effectively as when they are instructed. One example is a study by Buchner (1994) who used a perceptual clarification task to assess grammar knowledge

[1]By using the term “rule” we are not presupposing subjects’ use of rules over other forms of knowledge (e.g., exemplars). We are simply referring to the task in which subjects are asked to make grammaticality judgements after being informed of the complex rules.

indirectly in an artificial grammar task. He found that both subjects who were and those who were not informed about the regularities in the strings or the link between the training and the test phases were faster in identifying grammatical over non-grammatical strings.

A further indirect measure that has been claimed to show this equal sensitivity to grammar knowledge—and the one of interest in this paper—is a variation of the mere exposure effect paradigm (Manza & Bornstein, 1995; Manza et al., 1999). The mere exposure effect is the finding that repeated exposure to a stimulus causes increased liking of that stimulus (Zajonc, 1968). It has been demonstrated in over 200 investigations across a wide range of stimuli (Bornstein, 1989). It is therefore a robust, sensitive and, importantly, indirect measure of the application of a representation of prior experiences (Whittlesea & Wright, 1997).

The first study to combine the mere exposure and implicit learning paradigms was that of Gordon and Holyoak (1983). They found that subjects demonstrated a greater liking for grammatical items over non-grammatical items following a typical artificial grammar experiment training phase. They attributed this result to a generalization of the mere exposure effect. The importance of Gordon and Holyoak's finding is that it provides evidence of an application of prior experience with the grammar, in spite of subjects not being informed about the existence of the grammar before making their liking rating. As such, the liking rating provides an indirect measure of knowledge that satisfies the criteria for an indicator of implicit processing. Indeed, Vinter and Perruchet (1999) have recently singled out the liking-based grammar task as conforming to their *neutral effect criterion*. They argue that most implicit learning paradigms have great difficulty in providing evidence for implicit processing because the behavioural parameter upon which most studies focus is not neutral with respect to the potential influence of deliberately deployed explicit knowledge about the task. However, in the liking-based grammar task even if subjects know about the existence of underlying structure, there is no a priori reason for subjects to like grammatical items more than non-grammatical items.

Manza and colleagues (e.g., Manza, Zizak, & Reber, 1998) have provided further demonstrations of the effectiveness of liking ratings as a measure of grammar knowledge. Manza and Bornstein (1995) replicated Gordon and Holyoak's original finding and in addition found that explicit rule knowledge of the grammar was less pronounced in a group asked to make liking ratings than in a group asked to classify items on the basis of rules. Manza et al. (1999) describe the increased liking of grammatical over non-grammatical items as the "structural mere exposure effect" (SMEE), because the effect is shown to generalize to items with a related structure (grammatical test items). This is an extension of the normal mere-exposure effect that is observed when identical stimuli are shown at training and test.

The studies of Manza and colleagues and Gordon and Holyoak (1983) seem to show that the SMEE provides a sensitive indirect measure of grammatical knowledge. Gordon and Holyoak argued that the greater liking of grammatical over non-grammatical stimuli was due to affective responses being based, in part, on "complex processes that abstract structural regularities" (p. 496). Similarly, Manza and Bornstein (1995) argue that subjects who are not informed of the existence of the grammar are able to acquire and utilize its structure *just as well* as those who are informed.

To test the claims made about liking judgements we examined whether conditions that give rise to the ability to discriminate grammatical from non-grammatical items in a standard rule task also give rise to this ability in a liking task. If liking and rule judgements are equally sensitive to grammar knowledge then there should be no difference between the ability to discriminate items on the basis of affect and on the basis of rules. If, however, the two judgements are differentially sensitive to this knowledge we would expect a dissociation. The experiments reported here attempt to distinguish between these possible alternatives.

Experiment 1 addresses the generalizability of the SMEE by determining whether it transfers to items that bear the same underlying structure but a different surface structure. A robust finding in the artificial grammar literature is that subjects are able to classify items as grammatical or non-grammatical even when the letter set on which the items are instantiated is changed between training and test (Brooks & Vokey, 1991; Mathews et al., 1989; Reber, 1969). This finding has been interpreted as evidence that subjects acquire some knowledge about the structure of training items. If discrimination in the indirect liking task relies on this same structural knowledge then we should observe a similar pattern of transfer performance. If, on the other hand, grammatical discrimination with a changed surface structure is dependent on subjects being aware of the grammar and the crucial link between training and test—prior to making their judgements—then we would expect no difference between the liking of grammatical and nongrammatical items. Distinguishing between these accounts is the purpose of Experiment 1.

EXPERIMENT 1

Method

Subjects

A total of 36 undergraduate students from the University of New South Wales participated in the experiment in return for course credit. None of the subjects had taken part in any previous research involving implicit learning or affective preference tasks.

Materials

Stimuli for the experiment were generated using the finite-state grammar shown in Figure 1. For the memorization phase of the experiment 16 items representing all possible state-to state transitions of the grammar were selected for presentations. Items ranged from three to seven letters in length. For the classification tasks a 64-item list was generated. This contained 32 items that followed the rules of the grammar (grammatical items) and 32 items that violated the grammar (non-grammatical items). Consistent with previous research (Manza & Bornstein, 1995; Vokey & Brooks, 1992), non-grammatical items contained at least one letter in a position that was not permitted by the rules of the grammar. For the same-letter-set group both memorization and classification items appeared in the M, Q, X, R, T letter set. For the changed-letter-set group, M, Q, X, R, T were substituted in the classification items by the letters W, N, Z, S, P, respectively (see Figure 1).

Design

This experiment used a $2 \times 2 \times 2$ design. Letter set (same or changed) was the between-subjects factor; judgement type (rule or liking) and grammaticality (grammatical or non-grammatical) were the within-subjects factors.

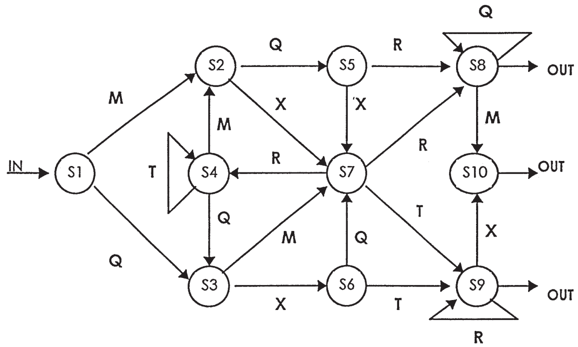

Figure 1. The artificial grammar (adapted from Vokey & Brooks, 1992) used to generate training and test items in Experiments 1, 2, and 3.

Control group

Before carrying out the study, it was necessary to determine that the items used for the classification tasks had no inherent qualities that could bias either liking or rule judgements. To control for this possibility a further 18 subjects were presented only with the classification items (in the M, Q, X, R, T letter set) and asked to perform both the rule and liking judgements. Results from this control group are presented alongside the experimental group to facilitate comparisons.

Procedure

Consistent with previous research (e.g., Reber, 1967) participants were informed that the experiment was a test of their memory. They were told that their task was to attend to and attempt to memorize as much as possible about the items that would be presented to them. They were then shown the 16 memorization items in a random order. This procedure was repeated five times for a total of 80 presentations. Each item remained on the screen for 5 s after which it was replaced by a new item. Participants made no overt response during this phase of the experiment.

At the end of the memorization phase participants were instructed that they were about to see some more items and that they were required to rate how much they liked each item. They were informed that there were no correct or incorrect answers for the task, but that they were simply to rate each item on its aesthetic appeal. The 64 classification items were presented sequentially in the centre of the screen in a random order; 10 s were allowed for each decision. Participants used the following scale (taken from Manza & Bornstein, 1995) to make their decisions: 6 = " I REALLY LIKE this item", 5 = "I LIKE this item", 4 = "I SORT OF LIKE this item", 3 = "I SORT OF DON'T LIKE this item", 2 = " I DON'T LIKE this item", and 1 = "I REALLY DON'T LIKE this item". The scale was printed on a piece of paper and placed next to the computer keyboard. Participants made their responses by pressing the number on the keypad that corresponded to the appropriate statement.

On completion of the liking ratings, participants were informed that the items they had attempted to memorize in the initial phase of the experiment were formed by a complex set of rules that determined which letters could appear before or after other letters. Participants in the changed-letter-set group were given additional information about how an item could have the same deep structure but a different surface structure (the items AAIIOUO and YYZZKSK were given as examples). Participants in both groups were then shown the same 64 items that they had previously rated for affect (though they were not informed that the items were the same) and were asked to classify each item as following the rules or not. For this rule judgement the scale read as follows (taken from Manza & Bornstein, 1995): 6 = "I'm

REALLY SURE this item FOLLOWS the rules", 5 = "I'm SURE this item FOLLOWS the rules", 4 = "I'm SORT OF SURE this item FOLLOWS the rules", 3 = "I'm SORT OF SURE this item DOES NOT FOLLOW the rules", 2 = "I'm SURE this item DOES NOT FOLLOW THE RULES", and 1 = "I'm REALLY SURE this item DOES NOT FOLLOW the rules". The placing of the scale and the recording of responses was the same as for the liking rating.

At the conclusion of both these tasks participants were asked to write down any of the reasons or criteria that they used in making their decisions first in the liking task and then in the rule task.

Results

One subject from the same-letter-set group was excluded from analysis for failing to follow instructions. This resulted in 17 subjects in the same-letter group and 18 in the changed-letter and control groups.

Mean liking and rule-following ratings for each cell of the 2 × 2 × 2 design (Letter Set × Judgement Type × Grammaticality) are shown in Table 1 along with the mean liking and rule ratings for the control group.

The data (excluding control subjects) were analysed by an analysis of variance (ANOVA) along with planned t tests for individual paired comparisons. A .05 level of significance was used in all cases.

The analysis revealed a significant main effect of grammaticality on classification ratings, $F(1, 33) = 13.33, p < .01$. There was no main effect of letter set, $F(1, 33) = .11$ $p > .05$, or judgement type, $F(1, 33) = 3.65, p > .05$. However, the interaction between grammaticality and letter set was significant, $F(1, 33) = 7.68, p. < .01$, as was the interaction between judgement type and grammaticality, $F(1, 33) = 5.35, p < .05$. Paired comparisons revealed that these interactions were due to grammaticality having a larger effect on rule decisions than liking ratings and on decisions involving same-letter set than those involving changed-letter set. Subjects in the same-letter-set group rated grammatical items higher than non-grammatical items in both the liking task, $t(16) = 2.34, p < .05$, and the rule judgement task, $t(16) = 3.54, p < .01$. In contrast, subjects in the changed-letter-set group only rated grammatical items higher than non-grammatical items in the rule judgement task, $t(17) = 2.03, p < .05$ (nearing two-tailed significance). For the liking task, nongrammatical items were rated slightly higher but this difference was not significant, $t(17) = 0.92, p > .1$.

A separate 2 (grammaticality: grammatical or non-grammatical) × 2(judgement type: liking or rule) ANOVA was conducted on control subjects' data. As expected, this revealed that the

TABLE 1
Experiment 1: Classification performance with grammatical and non-grammatical items

	Liking				*Rule*			
	Grammatical		*Non-grammatical*		*Grammatical*		*Non-grammatical*	
Group	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Same letter	3.70	0.56	3.51	0.59	3.88	0.46	3.54	0.56
Changed letter	3.39	0.82	3.46	0.81	3.86	0.44	3.71	0.38
Control	3.48	0.48	3.44	0.48	3.57	0.39	3.54	0.32

Note: Numbers are Mean rating of items on a 6-point scale where 1= "least liking" or "least rule conforming".

grammaticality of items had no main effect on subjects' ratings, $F(1,17) = 0.71$, $p > .1$. Although in both the liking task and the rule task grammatical items were rated slightly higher than non-grammatical items the differences were not reliable: liking, $t(17) = 0.51$, $p > .1$; rule, $t(17) = 0.53$, $p > .1$. There was no main effect of judgement type, $F(1,17) = 1.13$, $p > .1$. The interaction of grammaticality and judgement type did not approach significance. We concluded from this that neither the grammatical nor the non-grammatical stimuli were inherently likeable or distinguishable from each other on the basis of grammaticality.

Discussion

The purpose of this experiment was to see if the SMEE generalized to stimuli bearing the same underlying structure but a different surface structure. The finding that subjects in the changed-letter group did not like grammatical items any more than non-grammatical items indicates that under these circumstances the SMEE does not transfer across different surface representations. This result is in direct contrast to findings recently reported by Whittlesea and Wright (1997). They found a marginal effect of grammaticality on liking judgements with a changed-letter set. This small transfer effect was inconsistent with other findings reported by Whittlesea and Wright and may have been due to the highly repetitive structure of the grammar that they used.[2]

The greater liking of the grammatical items in the same-letter group replicates the findings of Manza and Bornstein (1995) and Gordon and Holyoak (1983) and provides further evidence that the liking task is a sensitive measure of some aspect of grammar knowledge. However, the significant interaction between judgement type and grammaticality revealed that when subjects were not informed of the existence of the grammar (during the liking task) they were not able to utilize the knowledge of its structure as well as when they were told about it (during the rule task). Thus, although liking ratings are influenced to some extent by prior exposure to grammatical items, they do not seem to be as sensitive an index of learning as the rule judgements.

Results from the rule task replicate the standard findings that subjects can apply grammar knowledge when asked to classify on the basis of grammaticality—both when the letter set is the same and when it is changed between training and test (e.g., Brooks & Vokey, 1991; Mathews et al., 1989).

Support for the notion that the liking task is indeed an indirect measure of knowledge comes from verbal report data. In response to the question asking about how decisions in the liking task were made, only one subject (from the same-letter group) mentioned liking items that "seemed recognizable" from the training phase. Inspection of this subject's results showed a greater liking for grammatical items. However, interestingly, the subject rated

[2]Whittlesea and Wright (1997, Experiment 4) used a deterministic grammar in contrast to the Markovian one used in the present studies. Their deterministic grammar gave rise to items with highly salient repeated patterns. Furthermore, their transfer stimuli had a direct correspondence with training items, such that the training item RMRMCTX was seen at test as QFQFSPL. These two qualities of the stimuli (neither of which are possessed by the stimuli employed in the present study) may have contributed to the marginal transfer effect that they report. To examine this issue we attempted to replicate the effect of grammaticality on liking, using the stimuli from the Whittlesea and Wright experiment. Unfortunately, we failed to find the effect even with a larger sample size (16 compared to 11 in the Whittlesea and Wright study).

grammatical items lower than non-grammatical in the rule task in spite of stating that her decisions in this task too had been based on similarity to training items. This pattern suggests that this subject was not explicitly applying veridical knowledge. In contrast, all the subjects reported some attempt at recall of training items when making rule judgements.

It is apparent from Experiment 1 that subjects are acquiring some information during training that is affecting their responses in the liking task. The information, however, is not transferable to a new letter set. Experiment 1 has demonstrated that experience with grammatical strings leads to an increased liking of grammatical test items, provided their surface representation is similar. Previous research (e.g., Perruchet & Pacteau, 1990) has shown that, for the standard grammaticality test, experience with fragments of strings is sufficient for subjects to become sensitive to the underlying regularities of artificial grammars. In other words, subjects are able to acquire enough information to discriminate grammatical from non-grammatical items on the basis of rules, simply through exposure to grammatical pairs of letters.

Perruchet and Pacteau (1990) compared the performance of a group trained on bigrams (two-letter units) with a group trained on whole strings (three to six letters in length) and found an almost identical ability to classify novel items as grammatical or non-grammatical in the standard rule judgement task. We acknowledge that Manza and Reber (1997) were unable to replicate these findings; however, due to their "considerably smaller sample size" (p. 94) they conceded that their conclusions could only be treated as tentative. Thus, in line with the findings of Perruchet and Pacteau, we can be fairly confident that knowledge of simple letter co-occurrences is sufficient for grammatical discrimination in the rule task. In Experiment 2 we question whether this simple knowledge of letter co-occurrences is also sufficient for the indirect measure of grammar learning. If the increase in liking of grammatical items is a reflection of grammar knowledge, and exposure to bigrams gives rise to grammatical discrimination in the rule task, then subjects trained on bigrams should demonstrate a similar ability to discriminate items on the basis of liking. In contrast, if knowledge of letter co-occurrences is not enough to give rise to the SMEE then liking ratings will not be affected by the grammatical status of test items.

EXPERIMENT 2

Method

Subjects

A total of 24 undergraduate students from the University of New South Wales participated in the experiment in return for course credit. None of them had taken part in any previous research on artificial grammar learning or affective preference tasks.

Materials

Two sets of stimuli were generated for the memorization phase of the experiment. The strings group was presented with the same 16 items used in the memorization phase of Experiment 1. The 16 items were made up of a total of 101 letters. Subjects in the pairs group were presented with the same letters but paired for presentation. The frequency of presentation of the resulting 50 pairs (the number was rounded down from 50.5) was calculated using the same method as that of Perruchet and Pacteau (1990). To illustrate: the pair MX occurs seven times in the strings groups' items in a total of 85 pairs (the reference value is 85 and not 50.5 because each letter of a string, with the exception of the first and last, enters into two different pairs). Thus MX was presented $(7/85) \times 50 = 4.1$ times, rounded off to 4 times to the pairs group.

Design

A $2 \times 2 \times 2$ design was used in this experiment. Memorization item type (string or pair) was the between-subjects factor. Judgement type (rule or liking) and grammaticality (grammatical or non-grammatical) were the within-subjects factors.

Procedure

Subjects were allocated at random to either the string group or the pair group. The procedure was identical to that of the same-letter group in Experiment 1. Prior to presentation of the items subjects were informed that the experiment was a test of their memory and that they would have to attend to and attempt to memorize as much as possible about the items that would be presented to them. For the strings group the 16 items were then presented on a screen one at a time for 5 s in a random order. This cycle was repeated five times for a total of 80 presentations. For the pairs group the 50 items were presented one at a time for 1.5 s (the time on screen was reduced to make the total duration of the memorization phase comparable for both groups). Again, the cycle was repeated five times for a total of 250 presentations.

The liking task followed on immediately from the end of the memorization phase. The 64 classification items (32 grammatical and 32 non-grammatical items) were presented individually in a random order and subjects were instructed to rate how much they liked each item. The same 6-point scale as that employed in Experiment 1 was used, and subjects responded by pressing the appropriate number key. On completion of the liking task subjects were informed of the existence of the grammar and were then asked to carry out the rule judgements. The same 64 items were then presented in a different random order. The 6-point rule following scale was used and responses were recorded via the keyboard.

After completing both these tasks subjects were asked to write down any reasons or criteria they used in both their liking decisions and their rule judgements.

Results

Mean ratings for grammatical and non-grammatical items are shown for each cell of the 2 (memorization item type: string or pair) × 2 (judgement type: rule or liking) × 2 (grammaticality: grammatical or non-grammatical) design in Table 2.

The data were analysed by an ANOVA along with planned t tests for individual paired comparisons. A .05 level of significance was used in all cases.

The analysis revealed a significant main effect of grammaticality, $F(1, 22) = 14.27, p < .01$. There were no main effects of judgement type, $F(1, 22) = 0.10, p > .1$, or memorization item type, $F(1, 22) = 0.26, p > .1$. However, the interaction between judgement type and grammaticality was significant, $F(1, 22) = 10.08, p < .01$. Paired comparisons showed that this interaction was due to grammaticality exerting a stronger influence on rule judgements than liking ratings. Subjects in the strings group rated grammatical items higher than non-grammatical items, and this result was significant in both the liking task, $t(11) = 2.37, p < .05$, and the rule judgement, $t(11) = 3.04, p < .05$, replicating the same letter group of Experiment 1. In contrast, subjects presented with pairs in the memorization phase rated grammatical items

TABLE 2
Experiment 2: Classification performance with grammatical and non-grammatical items

	Liking				*Rule*			
	Grammatical		*Non-grammatical*		*Grammatical*		*Non-grammatical*	
Group	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Strings	3.64	0.48	3.43	0.60	3.80	0.40	3.44	0.52
Pairs	3.56	0.68	3.53	0.70	3.59	0.70	3.20	0.61

higher than non-grammatical items but the difference was only reliable for the rule judgement: liking, $t(11) = 0.34$, $p > .1$, rule $t(11) = 2.96$, $p < .05$.

Discussion

The aim of this experiment was to determine whether the SMEE is dependent on subjects' exposure to whole strings during training or to fragments of those strings. The results show that subjects only display a greater liking for grammatical over non-grammatical test items when they have attempted to memorize whole strings. Consistent with Experiment 1 the interaction of judgement type and grammaticality indicates that the effect of grammaticality is stronger in the rule task than in the liking task. In contrast, exposure to either strings or letter pairs is enough to give rise to the grammaticality effect in the rule task. This latter finding replicates that of Perruchet and Pacteau (1990) who similarly found almost equal classification performance for subjects trained on pairs or strings. It is worth noting that Gomez and Schvaneveldt (1994) failed to find evidence of learning in a group trained on bigrams. They argued that Perruchet and Pacteau's result could have been due to the high number of non-permissible letter pairs in the non-grammatical items that they used, as well as salient violations of the grammar involving multiple letters. Gomez and Schvaneveldt used carefully generated stimuli in which both letter associations and letter positions were controlled for. In the present experiment the principal interest was in the information used by subjects in the liking task rather than the rule task; therefore we did not control for permissible pair or permissible location violations. It is therefore possible that the effect of grammaticality in the rule task is due largely to subjects' explicit knowledge of grammatical violations involving salient non-permissible pairs. Verbal report data reinforce this suggestion as 7 out of 12 subjects in the pairs group mentioned basing their decisions on the presence or absence of double letters.

Further analysis of the verbal reports revealed less support than in Experiment 1 for the notion that the liking task is an indirect measure of knowledge. Six subjects (three from each group) mentioned basing liking decisions, to some extent, on information from the memorization phase. Of these six, four rated grammatical items higher than non-grammatical ones, and all six rated grammatical items higher in the rule task. This suggests that four of the subjects were explicitly applying accurate knowledge in both classification tasks.

Experiments 1 and 2 have demonstrated that liking judgements are a less sensitive measure of grammar knowledge than rule judgements. For liking judgements to reflect any sensitivity to the structure of the grammar, it seems that training and test stimuli need to have a highly similar surface representation. It has been suggested that the apparent sensitivity to structure exhibited by subjects in implicit learning situations is a by-product of the encoding operations performed on stimuli (Whittlesea & Dorken, 1993). Whittlesea proposes an episodic account of typical "implicit" learning in which the way a subject interacts with the stimuli critically determines what is learned about them. Evidence for this episodic account comes from a number of experiments that have manipulated processing context independently of any implicit structure and have found that subjects' sensitivity to this structure is determined by the particular operations performed on the stimulus materials. Whittlesea and Dorken (1993, Experiment 3) asked subjects to either spell or pronounce items generated by a grammar; in a subsequent false-recognition test, subjects were shown novel grammatical and non-grammatical items and were required first to spell or pronounce them and second to judge whether or not they had seen the items before. Whittlesea and Dorken found that subjects falsely recognized more grammatical stimuli as old but, furthermore, they were also more likely to classify an item as old if they had processed (spelled or pronounced) a structurally similar item in the same way at training and test. Whittlesea and Dorken argue that this result illustrates that subjects are not simply sensitive to the surface structure of items but that they impose organization on the items in response to specific demands of the task.

Experiment 3 investigates whether the SMEE found in Experiments 1 and 2 is an "apparent sensitivity" to structure by manipulating the context in which items are processed at training and test. If the effect of grammaticality on liking ratings is simply a reflection of sensitivity to the surface structure of the grammar, then, provided subjects are equally exposed to that structure, the SMEE should not be influenced by different processing operations. If, however, the sensitivity to structure is only an apparent sensitivity then incongruent processing operations at training and test may eliminate the SMEE.

EXPERIMENT 3

In Experiment 3 the encoding instruction given to subjects was manipulated. The performance of a group asked to spell both training and test items out loud forwards was compared with a group asked to spell training items backwards and test items forwards. It was hypothesized that if the basis of the SMEE is an apparent sensitivity to structural grammar knowledge then creating a mismatch between encoding and test-processing operations (backwards group) would eliminate the effect of grammaticality on liking ratings.

Method

Subjects

A total of 30 undergraduate students from the University of New South Wales participated in the experiment in return for course credit. None of the subjects had participated in Experiments 1 or 2 or any other research into implicit learning.

Materials

Training items were the same as those used in the same-letter-set group of Experiment 1 and the strings group of Experiment 2. The same 64 test items (32 grammatical and 32 non-grammatical instantiated on the M, Q, X, R, T letter set) as those used in the previous experiments were used for the liking task and the rule task.

Design

A $2 \times 2 \times 2$ design was employed. Encoding instruction (forwards or backwards) was the between-subjects factor; judgement type (rule or liking) and grammaticality (grammatical or non-grammatical) were the within-subjects factors.

Procedure

Subjects were allocated randomly to the "forwards" or "backwards" condition. Subjects sat at a computer monitor and were told that the experiment was to be a test of their memory. They were then shown the 16 training items. Training was subject paced. On one key press an item appeared in the centre of the screen, and subjects were instructed to spell the item out loud. Another key press removed the item and replaced it with the instruction to repeat the item out loud again from memory. A further key press brought up the next item. The 16 training items were shown five times in a random order for a total of 80 presentations. The only difference in procedure between the two conditions was that subjects in the forwards condition were simply instructed to spell the items out loud, whereas those in the backwards condition were asked to spell items out loud in reverse order (i.e., right to left).

The procedure at test was identical for both conditions. The 64 test items were shown once through, and subjects were required to spell each item out loud in the normal (left to right) order before making their liking decisions. Following this subjects were informed of the rule-governed nature of the stimuli that they had tried to memorize during training. They were then shown the 64 test items for a second time and told that half of them conformed to the rules and half of them did not. Subjects were then required to spell out each item forwards prior to making rule decisions.

After completing both these tasks subjects were asked to write down any information that related to how they had made their decisions in the two tasks.

Results

Table 3 shows the mean ratings for grammatical and non-grammatical items for each cell of the 2 (encoding instruction: forwards or backwards) $\times$ 2 (judgement type: rule or liking) $\times$ 2 (grammaticality: grammatical or non-grammatical) design.

A mixed ANOVA was conducted on the data, along with planned t tests for individual paired comparisons. A .05 level of significance was used in all cases.

A significant main effect of grammaticality was found, $F(1, 28) = 26.23, p < .01$. There were no main effects of encoding instruction, $F(1,28) = 0.05, p > .1$, or judgement type, $F(1, 28) = 0.01, p > .1$. However the interaction between grammaticality and encoding instruction was significant, $F(1, 28) = 8.60, p < .01$, as was the interaction between grammaticality and judgement type, $F(1, 28) = 24.19, p < .01$. Planned comparisons revealed that these interactions

TABLE 3
Experiment 3: Classification performance with grammatical and non-grammatical items

	Liking				*Rule*			
	Grammatical		*Non-grammatical*		*Grammatical*		*Non-grammatical*	
Group	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Forwards	3.65	0.57	3.54	0.54	3.87	0.62	3.30	0.66
Backwards	3.58	0.53	3.69	0.65	3.76	0.59	3.47	0.55

were due to the effect of grammaticality being greater on rule decisions than on liking decisions, and greater on decisions made by subjects who encoded items forwards than those made by subjects who encoded them backwards. Subjects in the forwards condition rated grammatical items higher than non-grammatical items. This was significant both for the liking task, $t(14) = 2.31$, $p < .05$, and the rule task, $t(14) = 5.42$, $p < .01$, replicating the same-letter group of Experiment 1 and the strings group of Experiment 2. In contrast, subjects who encoded items backwards at training rated grammatical items higher than non-grammatical ones only in the rule task, $t(14) = 2.80$, $p < .05$. In the liking task, subjects rated non-grammatical items numerically higher than grammatical items, but the difference between the ratings was not reliable, $t(14) = 1.48$, $p > .1$.

Discussion

The aim of Experiment 3 was to determine the influence of an instruction to encode training items backwards or forwards on liking and rule ratings. The results demonstrate that an instruction to encode items forwards gives rise to an effect of grammaticality in both the liking and the rule task, when this context is re-established on test. Consistent with Experiments 1 and 2, the effect is stronger on the rule task, suggesting that the rule task is a more sensitive test of grammar knowledge. In contrast, an instruction to encode items backwards removes the effect of grammaticality on liking ratings, but leaves the effect on rule ratings reduced, although intact.

It is important to note that the exposure to the grammatical structure of the items was exactly the same for both groups so the differences observed are most likely to be due to the processing operations performed. The finding that a mismatch between encoding and test processing eliminates the SMEE suggests that it is not simply a reflection of knowledge of surface structure. Rather the effect seems to be mediated to some extent by memory for the context in which previous grammatical stimuli were processed.

Analysis of verbal reports revealed that only one subject (in the backwards group) mentioned liking items that "seemed easily recognizable". However, this subject showed no difference in his liking of grammatical and non-grammatical items.

GENERAL DISCUSSION

The aim of the experiments presented here was to investigate the use of liking judgements in artificial grammar learning to determine whether they are as sensitive a measure of grammar knowledge as the standard rule judgements. The interaction of grammaticality and judgement type observed in all three experiments showed that liking judgements and rule judgements are differentially sensitive to grammar knowledge. Contrary to earlier claims (e.g., Manza & Bornstein, 1995) when subjects have not been informed of the existence of the grammar they are not able to utilize its structure as well as when they have been informed.

For an effect of grammaticality to be found on liking ratings it seems that encoding and testing conditions need to be highly similar, both in terms of the stimuli encountered and in terms of the operations carried out on the stimuli. In contrast, the knowledge used to make grammaticality judgements in the rule task appears more flexible and robust. Rule judgement knowledge can transfer to items that bear the same underlying structure but a different surface structure (Experiment 1) and from fragments of items to whole items (Experiment 2), and it remains intact when encoding and testing processing manipulations are incongruent (Experiment 3). However, any one of these manipulations eliminates the effect of grammaticality on liking ratings.

In order to perform the more complex types of learning, in which encoding and testing are not highly similar, it seems that subjects need to be made aware of the critical link between training and test. As we have argued, being aware of this link makes it highly likely that subjects use explicit strategies in their test decisions. Thus it seems that complex learning is mediated to some extent by explicit knowledge. This conclusion is consistent with the findings of Gomez (1997), which show that complex learning, such as learning second-order dependencies or transferring knowledge to items with a changed surface structure, is tied to explicit knowledge. The importance of congruency between encoding and test of both stimuli and the operations performed on them leads us to conclude that the pattern of data obtained in the three experiments is better predicted by processing accounts of learning (e.g., Whittlesea & Dorken, 1993) than by an account of learning based on a discrete system capable of unconscious abstraction of deep structure (e.g., Reber, 1989).

In all three experiments there was a small but consistent effect of grammaticality on liking ratings, when encoding and testing conditions were highly similar. Even when subjects have not been informed of the existence of the grammar, they are able to utilize some knowledge acquired during training. The pattern of data suggests that both liking ratings and rule judgements access the same knowledge base but that liking ratings are less sensitive to this knowledge. The liking ratings are, however, sensitive to a degree of knowledge (enough to discriminate grammatical from non-grammatical items when encoding and testing conditions are consistent), and the question still remains as to how this sensitivity is manifested.

One potential answer to this question is perceptual fluency. Recent accounts of the standard mere-exposure effect (e.g., Bornstein & D'Agostino, 1992; Seamon, McKenna, & Binder, 1998) have suggested that the effect may be based on a misattribution of perceptual fluency to a feeling of liking. It is possible that a similar process underlies the "structural" mere-exposure effect. Perceptual fluency is defined as the facilitation of stimulus encoding resulting from encoding practice (Jacoby & Dallas, 1981). The suggestion is that at test subjects process previously exposed stimuli more easily and that they attribute this ease of processing to liking. In the grammar task, grammatical items seen at test are closer in structure to training items than are non-grammatical items. This means that a subject might process (possibly by spelling out the item at a sub-vocal level) a grammatical item more fluently than a non-grammatical one, because they have had practice with memorizing grammatical items during training. This ease of processing may then be attributed to liking.

Support for this account comes from Whittlesea (1993, Experiment 5), who reports an effect of processing fluency on pleasantness ratings of natural word stimuli—even in the absence of prior exposure to the critical words. He argues that the increased preferences may be attributed to efficient processing of test words (through, for example, their presentation within semantically predictive contexts) and not necessarily to their previous exposure. With regards to the grammar task, we are suggesting that a grammatical test item, although it has not been previously presented, will be processed more efficiently due to it having a closer resemblance to training items than have non-grammatical test items. Further support for this argument comes from recent findings that document the increased fluency of processing of grammatical over non-grammatical items (Whittlesea & Leboe, 2000)

This account is consistent with the findings of the experiments reported here. In Experiment 1 there would only be a processing fluency advantage for stimuli bearing the same surface structure, so no effect of grammaticality on liking would be expected for the changed-letter set. Similarly, in Experiment 2, memorizing letter pairs confers little or no ease-of-processing advantage to whole strings. Finally, in Experiment 3, making the encoding and testing operations incongruent would eliminate any processing fluency and with it any effect of grammaticality on liking. Anecdotal evidence from subjects' verbal reports in Experiment 3 supports this conclusion. A total of 9 out of 15 subjects in the forwards group reported that they liked the items that were easier to say out loud.

If subjects are attributing ease of processing to liking, a question remains as to what this attribution is based on. Verbal report data are inconclusive but there is some suggestion that subjects may be aware of the basis for their attributions. The reports suggest that subjects try intentionally to give higher liking ratings to the items that they perceive as similar to those seen during the training phase. If this interpretation is correct, then the small effect of grammaticality on liking may only be due to those subjects who are aware of the relationship between the memorization phase and the liking task. This interpretation is supported by analysis of the data from Experiment 2 after removal of aware subjects (those who exhibited explicit application of veridical knowledge): The effect of grammaticality on liking disappears.

The preceding explanation of the liking effect does not require recourse to a separate implicit learning or memory system and as such is consistent with a recent processing account of the liking-without-recognition effect observed in many studies of mere exposure (e.g., Kunst-Wilson & Zajonc, 1980; Seamon, Brody, & Kauff, 1983; Seamon et al., 1998). Whittlesea and Price (1999) suggest that the effect is not based on implicit memory (as has been commonly stated, e.g., Seamon et al., 1998) but can be explained in terms of the different explicit processing approaches adopted by subjects when making liking and recognition judgements. Whittlesea and Price argue that the non-analytic strategy used in liking judgements gives rise to processing fluency and consequently feelings of familiarity, whereas the analytic strategy typical of a recognition judgement prevents fluency from being experienced.

Conclusions

The experiments reported here have demonstrated the differential sensitivity of two measures of the knowledge acquired in artificial grammar learning. A direct measure of knowledge—the standard rule judgement—is sensitive to complex forms of learning. A more indirect measure (though not completely indirect)—the liking rating—is only sensitive to learning in conditions where encoding and testing contexts are consistent.

We believe that the data suggest that both the rule and liking judgements access the same knowledge base to different degrees. It should be noted that our data are agnostic as to the exact nature of the underlying knowledge base. It appears that in making the rule judgements, subjects are relying on some knowledge of the structural aspects of the strings, but it remains to be seen exactly what this knowledge entails. Recent investigations are bringing us closer to an understanding (e.g., Gomez, Gerken, & Schvaneveldt, 2000; Johnstone & Shanks, in press; Tunney & Altmann, 1999), and we do not presume on the basis of these data to rule out the possibility that some abstract information is acquired through exposure to the training materials. We contend merely that if the liking effect represented an automatic consequence of exposure to the structural relations inherent in the grammar (e.g., Manza & Bornstein, 1995; Manza et al., 1998) then arguably it should have been robust in the face of the manipulations that we employed.

We acknowledge that our failure to find a robust SMEE may have been a result of insufficient study processing. We chose to use a simple observation procedure to ensure consistency between our experiments and those of Manza and Bornstein (1995), but this may have led to a relatively low level of learning. However, we note that studies using the same observation technique have given rise to a degree of learning sufficient to support quite radical transfer across both surface representations and modalities (Altmann, Dienes, & Goode, 1995; Dienes & Altmann, 1997). The extent to which the expression of the SMEE is reliant on the processing demands of the study task is an empirical issue that requires further investigation.

In conclusion, we propose that our results lend support to a processing account of learning (Whittlesea & Dorken, 1993) in which what is learned is predicted by an interaction of the properties of stimuli and the operations carried out on the stimuli to satisfy the demands of the current task. The greater sensitivity of the rule judgement seems to be a reflection of attempts to explicitly recall information from the memorization phase. The less sensitive liking ratings seem to be a measure of the fluency with which test items are processed. One important avenue for future research is to determine exactly how processing fluency contributes to the interaction of stimulus properties and test demands in artificial grammar learning.

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