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The Conscious, the Unconscious, and Familiarity

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This article examines the role of subjective familiarity in the implicit and explicit learning of artificial grammars. Experiment 1 found that objective measures of similarity (including fragment frequency and repetition structure) predicted ratings of familiarity, that familiarity ratings predicted grammaticality judgments, and that the extremity of familiarity ratings predicted confidence. Familiarity was further shown to predict judgments in the absence of confidence, hence contributing to above-chance guessing. Experiment 2 found that confidence developed as participants refined their knowledge of the distribution of familiarity and that differences in familiarity could be exploited prior to confidence developing. Experiment 3 found that familiarity was consciously exploited to make grammaticality judgments including those made without confidence and that familiarity could in some instances influence participants' grammaticality judgments apparently without their awareness. All 3 experiments found that knowledge distinct from familiarity was derived only under deliberate learning conditions. The results provide decisive evidence that familiarity is the essential source of knowledge in artificial grammar learning while also supporting a dual-process model of implicit and explicit learning.

Keywords: implicit learning, artificial grammar learning, familiarity, subjective measures, unconscious knowledge

Performance in implicit learning tasks appears to show an ability to acquire representations of abstract properties, knowledge beyond the specifics of individual learning events. A central question in cognitive psychology has been whether this ability requires a separate mechanism or can be accounted for by a single process such as familiarity. Computational models of implicit learning assume a continuous output variable, most often supposed to be familiarity (for a review see Cleeremans & Dienes, 2008). Signal detection analyses that successfully fit responding in implicit learning tasks are similarly consistent with a continuous underlying dimension (Kinder & Assmann, 2000; Lotz & Kinder, 2006). Studies demonstrating a relationship between fluency and implicit learning imply a role of familiarity by assuming that fluency is experienced as familiarity (Buchner, 1994; Kinder, Shanks, Cock, & Tunney, 2003). Participants also have reported experiencing familiarity when responding to implicit learning tasks (e.g., Norman, Price, Duff, & Mentzoni, 2007). Indirect evidence for the role of familiarity in implicit learning is abundant, and yet to date no research has evaluated that process directly, that is, by examining the relationship between the subjective experience of familiarity and responding in an implicit learning task.

We present a detailed model of implicit learning of artificial grammars that is based on subjective familiarity and evaluate it by direct means—examining how both decisions and confidence relate to subjective reports of familiarity. Our results provide decisive evidence that familiarity is the essential source of knowledge in artificial grammar learning (AGL) under incidental learning conditions, irrespective of whether responses are typically taken to reflect conscious or unconscious knowledge. We explicate the process by which conscious judgment knowledge develops and present evidence that substantial knowledge distinct from familiarity is found only under deliberate learning conditions.

The AGL Paradigm and Assessing Unconscious Knowledge

AGL has been a useful paradigm for the investigation of implicit learning (Pothos, 2007; Reber, 1989). In a typical AGL experiment, participants are exposed to letter strings generated using a complex set of rules referred to as a *grammar*. Most often the strings are presented under the guise of a short-term memory task, with participants unaware of their rule-based nature. At test, after being informed of the existence of rules, participants judge which of a new set of strings are grammatical—typically discriminating them at above-chance accuracy (Reber, 1967). Participants also commonly rate their confidence in each judgment, with these ratings forming the basis of two subjective measures of unconscious knowledge: the guessing criterion (Cheesman & Merikle, 1986) and the zero-correlation criterion (Dienes, Altmann, Kwan, & Goode, 1995). The assumption underlying these measures is that a mental state is unconscious when a person does not think they are in that state (see Dienes, 2004, 2008). For example, by the guessing criterion participants have unconscious knowledge that a string is grammatical if they perform above chance in discriminating grammaticality whilst not believing they are able to do so. Studies have found AGL to result in unconscious knowledge as assessed by these measures (Allwood, Granhag, & Johansson, 2000; Channon et al., 2002; Dienes & Altmann, 1997; Dienes et al., 1995; Dienes & Longuet Higgins, 2004; Dienes & Perner, 2003; Tunney & Altmann, 2001).

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Confidence-based measures such as the guessing criterion establish awareness of knowing a string's grammaticality; this is termed *judgment knowledge*. Crucially, judgment knowledge relates only to knowledge of whether a string is grammatical. As such its absence cannot be taken to indicate the absence of *all* conscious knowledge relating to the decision task. For example, a participant may be aware that their response reflects a feeling of familiarity, but if they do not consider that feeling to be a veridical means of judging the string's grammaticality then they are not conscious of knowing whether the string is grammatical. They would not have confidence in judging its grammaticality and would hence be deemed to lack *conscious judgment knowledge*. If such judgments ultimately proved to have above-chance accuracy then the participant would be habitually using a reliable method of determining grammaticality without knowing it was reliable; they would have *unconscious judgment knowledge*.

Simple claims that the knowledge is conscious or unconscious ignore the range of experiences and mental states involved in AGL decisions. In order to establish the full extent of conscious knowledge, we need to assess the status of more than judgment knowledge. The present study extends assessment to include the strategies participants are aware of using to make their decisions. This additional information also permits a further important distinction to be made. Conscious knowledge of whether a string is grammatical does not require conscious knowledge of which features enabled that judgment, such as knowing it is ungrammatical because it contains the illegal letter pair "XT." Knowledge of the latter kind is termed *structural knowledge* (Dienes & Scott, 2005). A participant's reported decision strategy, together with their accuracy, can be used to evaluate the conscious status of structural knowledge. For example, an accurate judgment attributed to rules is taken to indicate the presence of *conscious structural knowledge*, whereas the same accuracy attributed to intuition is taken to indicate *unconscious structural knowledge*.

AGL and Familiarity

Reber (1967) originally proposed that participants acquire abstract rules of grammar that are distinct from the particular examples encountered during the learning episode. Since that time a range of alternative accounts have developed proposing that participants acquire relatively unprocessed knowledge of the training exemplars (e.g., Brooks, 1978; Whittlesea & Dorken, 1993). There has been considerable evidence that judgments are guided by knowledge of fragments, or chunks, of the training strings (Dulany, Carlson, & Dewey, 1984; Perruchet & Pacteau, 1990; Servan Schreiber & Anderson, 1990). Tunney (2005) further showed that the extent of these structural similarities predicted participants' confidence in their grammaticality judgments. Later studies have shown that performance is strongly predicted by the frequency with which such fragments are seen during training (Johnstone & Shanks, 2001; Knowlton & Squire, 1994). Other research has indicated that judgments depend in part on knowledge of whole training exemplars (Vokey & Brooks, 1992). There has also been evidence for a limited form of abstraction. Brooks and Vokey (1991) and Vokey and Higham (2005) showed that accurate discrimination of test strings transferred to a different letter set could be achieved by *abstract analogy* to specific training items—consistency in the repetition structure of training and test strings guiding grammaticality judgments.

In principle, the similarity of training and test materials, whether arising from whole string comparisons, fragments, or repetition structure, may influence responding by means of familiarity. Servan Schreiber and Anderson (1990) were the first to characterize the knowledge acquired in AGL in this way. The familiarity account holds that grammatical strings, by virtue of adhering to the grammar, are more likely to have properties seen during training and will consequently feel more familiar. Discrimination performance results from more familiar strings being endorsed as grammatical.

Persuasive evidence in favor of the familiarity account comes from analyses of receiver operating characteristics (ROCs). ROCs provide an indication of the underlying cognitive processes on which judgments are based, with rule-based and familiarity-based accounts implying different models (e.g., Yonelinas, 1994). Kinder and Assmann (2000) demonstrated that the ROCs for an AGL task are consistent with a signal detection model that assumes a continuous underlying dimension, which they postulate to be familiarity. Lotz and Kinder (2006) further demonstrated that ROCs remain consistent with a familiarity-based process under transfer conditions, suggesting that familiarity may arise from features such as repetition structure, which are preserved in such conditions. Tunney and Bezzina (2007) employed ROC analyses to dissociate the contribution of recollection and familiarity in AGL, concluding that the contribution arising from recollection declines with time, leaving only familiarity as the basis for judgments.

Further potential support for a role of familiarity has been provided by studies of processing fluency. Jacoby and Dallas (1981) proposed that when processing an item with relative ease, or fluently, people may attribute this to having seen the item before and experience it as familiarity. Whittlesea and Williams (2000) developed this notion further, demonstrating how familiarity arises from a discrepancy with expected fluency. Buchner (1994) found evidence that in AGL, grammatical strings were processed more fluently than ungrammatical strings (though for an alternative interpretation, see Scott & Dienes, 2008). Kinder et al. (2003) further demonstrated that artificially enhancing processing fluency in an AGL task increased the chance of strings being classified as grammatical.

If familiarity is derived from structural similarities between training and test strings, then the question is raised as to why those measures fail to fully account for classification performance (Higham, 1997; Meulemans & Van der Linden, 1997; Vokey & Brooks, 1992). However, no set of objective similarity measures can hope to capture all the regularities capable of contributing to subjective familiarity. Furthermore, even if it were possible to measure all objective similarities, subjective familiarity may also incorporate nonobjective aspects; for example, one string may be made more familiar because it contains elements of an individual's name or initials. Such sources of familiarity do not derive from structural similarities and will not contribute to accuracy, but they may nonetheless influence responding. Subjective ratings of familiarity, by capturing all such influences, should enable a more accurate assessment of the degree to which grammaticality judgments are related to feelings of familiarity.

Outstanding Questions for the Familiarity-Based Account of AGL

A number of accounts of implicit learning, and AGL in particular, have been proposed that either hold familiarity to have a central role or are compatible with that assumption (e.g., Dulany, 1997; Shanks, 2005). However, there are fundamental aspects of the familiarity-based account which have thus far been left unevaluated. To date no research has examined the basis of subjective feelings of familiarity in AGL. For familiarity to be the source of learning it must reflect objective properties of the test strings. Similarly, there has been no evaluation of how subjective feelings of familiarity relate to grammaticality judgments. In particular, there has been no evaluation of how grammaticality judgments map onto the distribution of familiarity among test strings or the extent to which familiarity predicts judgments depending on learning intention.

Finally, none of the work to date has addressed the extent to which participants are conscious of exploiting familiarity or the relation between familiarity and confidence. In particular, no work to date has addressed whether confidence is derived from differences in familiarity or whether participants can be aware of making choices that reflect differences in familiarity while still lacking confidence in those choices. Given that confidence forms the basis of subjective measures, its relation to familiarity is crucial to understanding the nature of unconscious knowledge as assessed by those measures.

The Calibrated Familiarity Model of AGL

We present a model of AGL, which we term the calibrated familiarity model (CFM), in which familiarity is the sole source of knowledge when learning is incidental but where deliberate learning can result in knowledge of other types. In evaluating the model's predictions we address each of the limitations thus far identified. Figure 1 illustrates the relationship between familiarity, grammaticality judgments, and confidence that is assumed by the CFM.

Subjective familiarity is assumed to be primarily derived from the structural similarity of training and test strings. Although there are anticipated to be other sources of familiarity, only those derived from the relation between training and test strings would contribute to accurate responding. Such influences would in principle include factors such as perceptual fluency; these influences themselves reflect similarities between training and test strings, that is, the effects of perceptual priming (though see Scott & Dienes, 2008, who found that although perceptual fluency has a small influence on familiarity, it is unrelated to grammaticality and thus not a source of accuracy). Importantly, the structural similarities contributing to familiarity are taken to include features such as repetition structure, thus enabling the model to account for performance under both standard and transfer conditions. Grammaticality judgments are made according to whether the subjective familiarity for a given string is thought to be above or below the estimated mean familiarity of the test strings, that is, typically, the intersection between the familiarity distributions of grammatical and ungrammatical strings. Confidence in grammaticality judgments is derived from the absolute difference between the subjective familiarity of a string and the estimated mean familiarity, and from the assessed reliability of that estimate. Thus confidence in grammaticality judgments may initially be absent even while the mean estimate is sufficiently accurate to support above-chance performance. For example, after seeing just three strings a participant's choice may reflect the difference in familiarity without the participant experiencing confidence in the judgment. After exposure to 30 strings, knowledge of the distribution of familiarity will be more reliable; as such, the same difference in familiarity may now support confidence in judging grammaticality. We refer to this

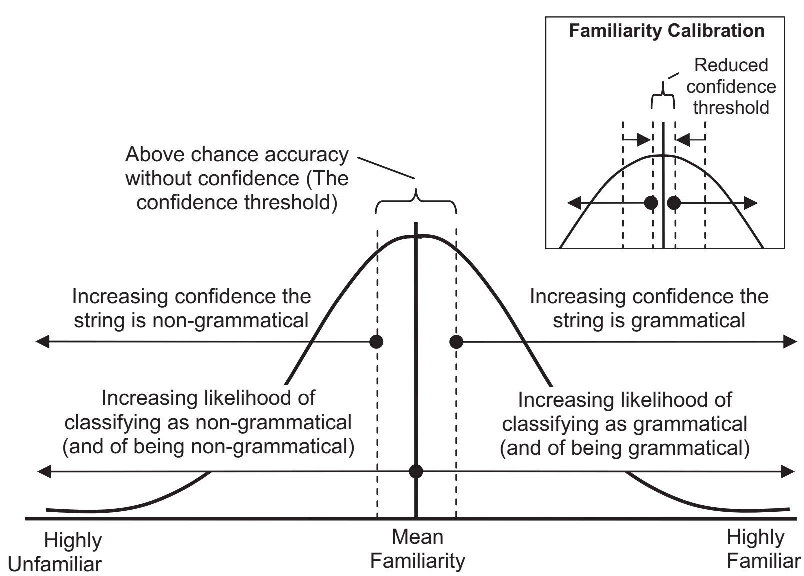

Figure 1. The calibrated familiarity model (CFM), which illustrates how familiarity is utilized to make grammaticality judgments and how confidence (and hence conscious judgment knowledge) emerges with calibration of the familiarity distribution.

process, whereby confidence becomes more tightly linked to familiarity, as *calibration* (see Figure 1 inset) and the gap between the estimated mean familiarity and that which gives rise to confidence as the *confidence threshold*. Calibration results in conscious judgment knowledge by establishing knowledge that the familiarity differences reliably predict grammaticality. The familiarity differences and awareness of their influence on the choices made may both already be conscious. We hold that higher order thoughts in general may arise through converting objective probabilities to subjective probabilities. Lau (2008), who also adopted a higher order thought theory, described a similar calibration process (of estimating signal and noise distributions in visual perception) as being the basis of conscious perception.

Under incidental learning conditions the knowledge acquired by participants is predicted to be based solely on familiarity—either directly, in the case of guesses and intuitions, or indirectly derived from familiarity, in the case of rules and memories. Any contribution of grammaticality over and above that of familiarity is predicted to be small or nonexistent. Under deliberate learning conditions, by virtue of individuals' opportunity to hypothesize about rules and to deliberately memorize exemplars during training, grammaticality is predicted to make a significant contribution to classification judgments over and above that of familiarity. The additional contribution of grammaticality is however predicted only for judgments knowingly based on rules and memories, that is, only in the presence of conscious structural knowledge.

Evaluating the Proposed Model

The standard AGL paradigm was employed with the usual grammaticality and confidence responses augmented with two new measures: familiarity and decision strategy. Familiarity ratings were given on a scale from 0–100, and decision strategy was selected from a list, for example, guess, intuition, rules, and memory. Experiment 1 examined the central claims of the proposed model: the basis of familiarity in AGL, its relation to grammaticality judgments and confidence, and how its use differs with learning intention. Experiment 2 replicated the key aspects of Experiment 1 and used a novel manipulation to evaluate the hypothesized calibration process. Finally, Experiment 3 replicated the common elements of Experiments 1 and 2 and examined participants' awareness of exploiting familiarity to make their judgments.

Experiment 1

Experiment 1 addressed the fundamental questions necessary to validate the proposed model. First, do objective similarities between training and test strings predict subjective familiarity and do they include features preserved under transfer conditions? Second, does familiarity predict grammaticality judgments and does this differ with learning intention (incidental vs. deliberate) and the extent of conscious knowledge (judgment knowledge vs. structural knowledge)? Third, is confidence predicted by the difference between the mean familiarity and that of the string being classified? Fourth, do familiarity differences below the confidence threshold continue to predict grammaticality judgments, thus contributing to above-chance performance when guessing?

Method

Participants

We recruited 80 participants from the University of Sussex library (40 men and 40 women). Participants' ages ranged from 18 to 33 years with a mean age of 22 (SD = 2.2). All participants were University of Sussex students and naive to the experimental hypothesis.

Materials

Two finite state grammars were used to generate the training and test strings. These were taken from Reber (1969). Both grammars used the same letter set (M, T, V, R, and X) and contained the same set of valid starting bigrams and final letters. Forty-five grammatical strings between five and nine characters in length were selected from each grammar. The training sets comprised 15 of the 45 strings repeated three times in different random orders. The test set comprised the remaining 30 strings from each grammar combined in random order. The selection of strings was made such that the same numbers of strings of each length were contained in both training sets and that the proportion of strings of each length was the same for training and test sets. Strings were presented in black at the center of a computer display with a letter height of 11 mm. The grammar strings used are listed in Appendix A.

Structural Similarity Measures

Statistics were calculated to gauge the structural similarity of test strings to those presented during training. The statistics used reflect those previously found to be effective predictors of grammaticality judgments in AGL, including associative chunk strength (Knowlton & Squire, 1996), chunk novelty (Meulemans & Van der Linden, 1997), specific similarity (Brooks & Vokey, 1991), and repetition structure (Mathews & Roussel, 1997). Repetition structure can be either *adjacent* (Mathews & Roussel, 1997) or *global* (Vokey & Brooks, 1992). Adjacent repetition structure reflects the similarity of a given letter to that immediately preceding it; for example, the adjacent repetition structure of AABBCC is 10101. The initial 1 represents the fact that the second letter is the same as the first letter; the following 0 indicates that the third letter is different than the second letter and so forth. Global repetition structure reflects whether any letter is the same as any other letter in the string; for example, the global repetition structure of the same string is 112233. In all, seven statistics were used: (a) string length in letters; (b) positional associative chunk strength (PACS), namely, the mean number of times the bigrams and trigrams contained in a test string appeared in the same letter position during training; (c) associative chunk strength (ACS), namely, the mean number of times bigrams and trigrams contained in a test string appeared during training irrespective of letter position; (d) novel chunk proportion (NCP), namely, the proportion of bigrams and trigrams in a test string that were not seen during training; (e) same letter proportion (SLP), namely, the maximum proportion of letters contained within a test string that appeared in the same location in a training string of the same length; for example, the pair ABAB and AAAA have a SLP of .5; (f) adjacent repetition proportion (ARP), namely, the maximum proportion of a test string's adjacent repetition structure that appeared in full (uninterrupted) in any of the training strings; (g) global repetition proportion (GRP), namely, the maximum proportion of a test string's global repetition structure that appeared in full (uninterrupted) in any of the training strings.[1]

Procedure

Training stage. Instructions for the look learning condition asked participants to look at each string while it was on the computer screen. This was intended to create a learning context that was more truly incidental than the usual practice of requiring participants to memorize the letter strings (see Reber & Allen, 1978). Instructions for the rules-search learning condition made participants aware that a complex set of rules dictated which letters could follow which other letters within the strings and requested that they attempt to discern the rules. Strings were presented one at a time for 5 s each with a 2-s blank screen between strings. Participants were not permitted to write or make notes during training.

Test stage. All participants were informed that the order of letters in the training strings had obeyed a complex set of rules and that exactly half of the strings they were about to see would obey the same rules. Instructions to participants in the familiarity condition requested that for each string they indicate the following in the answer booklet provided: the degree that the string felt familiar to them (0%–100%), whether or not they believed it to obey the same rules as those in the learning phase (yes or no, hereafter referred to as their *grammaticality judgment*), their confidence in this judgment (50%–100%, where 50% equaled a guess), and the decision strategy used to arrive at their judgment (guess, intuition, rules learnt in training, or memory of strings from training). Participants were instructed to use the decision strategy categories as follows: *guess* when the response was based on nothing but a pure guess and they thought they were equally likely to be right or wrong, *intuition* when the response was based on a feeling or a hunch such that they had some confidence but could not explain why, *rule* when the response was based on one or more rules and the nature of those rules could be stated if asked, and *memory* when the response was based on remembering part or all of one or more training strings. The memory category was intended to capture responses based on recollective memories. As such, it was emphasized that these responses should be based on specific memories of part or all of a training string and not on a sense of familiarity. Instructions for participants in the nonfamiliarity condition contained the same requests with the exception that they did not ask for familiarity ratings. This control group was included in order to test whether the request to rate the familiarity of strings influenced the nature of participants' grammaticality judgments. Test strings were presented on the computer display one at a time with participants permitted to advance through them at their own pace.

Design

A 2 × 2 × 2 between-participants design was employed with participants randomly assigned to conditions. The conditions included learning condition (look vs. rules search), familiarity condition (reported vs. unreported), and grammar condition (Grammar A vs. Grammar B). Grammar was a counterbalanced condition that we included to permit the use of the two-grammar design of Dienes and Altmann (1997). During training, half of the participants learnt Grammar A and half learnt Grammar B. At test all of the participants classified the same set of test strings, exactly half of which conformed to each of the two grammars. In this way the nongrammatical test strings for one group were grammatical for the other group, eliminating the need for an untrained control group. The order that strings were presented for classification was similarly varied and balanced across conditions.

Results

The following statistical procedures were adopted for this and all subsequent experiments reported in this article. An alpha level of .05 was used for all statistical tests and all reported confidence intervals are for 95% confidence. The individual regression equation method recommended by Lorch and Myers (1990) was adhered to for all multiple regression analyses, ensuring that within-participant predictors were tested against the appropriate error terms. Effect sizes are provided in the form of Cohen's d for difference scores and partial eta-squared (η_p^2) for analyses of variance (ANOVAs); see Cohen (1973) and Cohen (1977) for descriptions of these measures.

Influences on the Nature and Accuracy of Grammaticality Judgments

We examined the effect of each of the experimental manipulations (in each experiment) on both the accuracy of grammaticality judgments for each decision strategy and the proportion attributed to each decision strategy using ANOVAs. Analyses of the proportion of responses attributed to each decision strategy required conducting separate ANOVAs for each decision strategy, as the proportions sum to 1. The full ANOVAs and accompanying descriptive statistics for each of the experiments are provided in Appendix C. None of these analyses revealed significant effects involving familiarity condition, indicating that the requirement to report familiarity did not significantly influence the nature of grammaticality judgments. The pattern of significant results was not changed by excluding the familiarity condition. We therefore collapsed the general analyses that follow over familiarity condition, reporting differences between those conditions only where it is of specific interest.

Learning and the Question of Unconscious Knowledge

The mean percentage of correct grammaticality judgments, by decision strategy and learning condition, is given in Table 1. The overall percentage correct was significantly greater than chance, that is, 50% (M = 65, SE = 1.4), $t(79) = 45.77$, $p < .001$, d = 5.12, indicating that learning took place. The percentage of correct grammaticality judgments was significantly higher in the rules-search learning condition (M = 69, SE = 2.0) than in the look learning condition (M = 61, SE = 1.8), $t(78) = 3.24$, p = .002,

[1] Anchor chunk strength (Knowlton & Squire, 1994) was also evaluated as a potential predictor but was not found to make a significant additional contribution. This is likely to be due in large part to the fact that both grammars contain the same set of valid starting bigrams and final letters, thus reducing the relevance of anchor chunks. Furthermore, the measure of PACS will have captured any contribution of chunks in the anchor positions along with those throughout the string.

$d = 0.72$; nonetheless, performance in the look learning condition was above chance, $t(39) = 5.82$, $p < .001$, $d = 0.96$. For responses attributed to guessing, the percentage correct was greater than chance in the rules-search condition ($M = 64$, $SE = 3.1$), $t(33) = 4.48$, $p < .001$, $d = 0.77$, but not in the look condition ($M = 48$, $SE = 3.8$), $t(36) = 0.63$, $p = .535$, $d = -0.10$.[2] Hence, for participants instructed to search for rules, the guessing criterion indicated the presence of unconscious judgment knowledge. However, the extent to which this indicates that *all* knowledge relating to those judgments was unconscious has yet to be examined.

Structural Similarity Statistics as a Predictor of Familiarity

It was theoretically possible for familiarity to be related to the structural similarity measures independent of the training received. In order to evaluate this possibility, the correlations between familiarity and the similarity measures derived from the training strings were compared with those between familiarity and the similarity measures derived from the opposing grammar's training strings (cf. Dienes & Altmann, 2003). One-sample *t* tests (over participants) were used to test whether mean correlation coefficients were significantly different from zero, and paired-sample *t* tests were used to test the difference between coefficients for the learnt and opposing grammars (see Table 2). In all cases the correlation coefficients for learnt and opposing grammars were significantly different. Those for the opposing grammar's training strings were either nonsignificant or significant and in the opposite direction from those for the learnt grammar. That is, the observed relationship between familiarity and the structural similarity measures was the result of the training received and not a response bias.

Multiple regression was used to assess the degree to which the seven structural similarity measures uniquely predicted subjective familiarity ratings. Analyses were conducted separately for each participant collapsed across learning conditions.[3] The similarity measures accounted for a significant proportion (17%) of the variance in familiarity ratings (adj. $R^2 = .17$, $SE = .03$), $t(39) = 6.55$, $p < .001$, $d = 1.04$. This indicates that familiarity ratings do reflect the structural similarity of training and test strings. Length, NCP, SLP, and ARP each made individually significant contributions (see Table 3). The significant contribution of ARP, as a measure of repetition structure, is of particular interest. Repetition structure remains intact when the letters used to instantiate a grammar are changed. As such the contribution of ARP to familiarity will permit the relationship between familiarity and structural similarity to persist under transfer conditions.

Table 1
Experiment 1: Percentage of Correct Grammaticality Judgments (With Standard Errors) and Whether They Were Significantly Greater Than 50%

Condition	*df*	*M*	*SE*
Look			
Guess	37	49	2.7
Intuition	37	62^{**}	2.1
Rules	25	63^{**}	5.2
Memory	32	66^{**}	4.9
Rules search			
Guess	34	64^{**}	3.0
Intuition	39	64^{**}	2.4
Rules	30	76^{**}	3.9
Memory	34	78^{**}	2.7

** $p < .01$.

Table 2
Experiment 1: Mean Correlation Coefficients (With Standard Errors) for the Relationship Between Familiarity and Each Structural Similarity Measure Contrasted for Strings From the Training Grammar and the Opposing Grammar

	Training grammar		Opposing grammar		Difference	
Predictor	*M*	*SE*	*M*	*SE*	*M*	*SE*
PACS	$.24^{**}$	.03	$-.21^{**}$	.04	$.44^{**}$	.07
ACS	$.25^{**}$	.04	$-.26^{**}$	.04	$.50^{**}$	.08
NCP	$-.25^{**}$	.04	$.24^{**}$	.04	$-.49^{**}$	.07
SLP	$.19^{**}$	.02	$-.11^{**}$	.03	$.30^{**}$	.04
ARP	$.09^{**}$	.02	.02	.02	$.07^{**}$	.02
GRP	$.10^{**}$	.02	$-.15^{**}$	.03	$.24^{**}$	.04

Note. $df = 39$ for all tests. PACS = positional associative chunk strength; ACS = associative chunk strength; NCP = novel chunk proportion; SLP = same letter proportion; ARP = adjacent repetition proportion; GRP = global repetition proportion.
** $p < .01$.

Familiarity as a Predictor of Grammaticality Judgments

Consistent with predictions, the mean correlation between participants' familiarity ratings and grammaticality judgments (+1 grammatical, −1 ungrammatical) was substantial ($r = .68$, $SE = .03$), $t(39) = 25.20$, $p < .001$, $d = 4.00$, indicating that subjective familiarity did predict grammaticality judgments.[4] The more familiar participants rated a string to be the more likely they were to endorse it as grammatical. Multiple regression was used to evaluate the unique contribution of familiarity and grammaticality to participants' grammaticality judgments. The analyses were conducted separately by participant, decision strategy, and learning condition. The resulting mean standardized coefficients are presented in Table 4. Consistent with the model, familiarity made a significant contribution to grammaticality judgments even in the

[2] Note that in all cases where we evaluated guess responses we restricted analyses to guesses attributed a confidence of 50%. Contradictory responses—guesses with confidence greater than 50%—were excluded. These occurred only in Experiment 1 and amounted to just 3% of guesses.

[3] Comparisons of fragment statistics between learning conditions were also conducted but revealed no consistent differences across the three experiments.

[4] The correlation between familiarity and grammaticality could potentially have arisen simply from these two reports being taken in close temporal proximity. In order to eliminate this possibility, a separate experiment was conducted with familiarity ratings and grammaticality judgments reported in separate blocks. Despite the imperfect test–retest reliability of both grammaticality judgments ($M = 0.48$, $SE = 0.04$) and familiarity ratings ($M = 0.53$, $SE = 0.04$), the correlation between familiarity ratings and grammaticality judgments taken in separate blocks remained substantial ($M = 0.48$, $SE = 0.04$), $t(29) = 12.98$, $p < .001$, $d = 2.4$, confirming that their correlation reflects a genuine relationship.

Table 3
Experiments 1, 2, and 3: Mean Standardized Coefficients (With Standard Errors) for Familiarity Regressed on the Structural Similarity Measures

	Experiment 1		Experiment 2		Experiment 3	
Statistic	*M*	*SE*	*M*	*SE*	*M*	*SE*
Length	.10*	.04	−.01	.02	.00	.03
PACS	.04	.05	.15**	.03	.09*	.04
ACS	.00	.10	.14*	.06	.15	.08
NCP	−.18*	.08	.02	.04	.00	.08
SLP	.05*	.02	.14**	.02	.06*	.02
ARP	.12**	.02	.17**	.02	.18**	.03
GRP	.01	.03	−.04	.02	−.05	.03

Note. *df*s = 39 (Experiments 1 and 3) and 79 (Experiment 2). PACS = positional associative chunk strength; ACS = associative chunk strength; NCP = novel chunk proportion; SLP = same letter proportion; ARP = adjacent repetition proportion; GRP = global repetition proportion.
* $p < .05$. ** $p < .01$.

absence of confidence, that is, where responses were attributed to guessing. The contribution of familiarity was significant for all decision strategies with the exception of the rules category in the rules-search learning condition. This is notable, as it is where maximum conscious structural knowledge (in the form of rules) might reasonably be expected. The contribution of grammaticality over and above that of familiarity was consistent with predictions. Substantial contributions occurred only where decision strategies indicated the presence of conscious structural knowledge (rules and memory attributions) and were reported after deliberately searching for rules. The only significant contribution of grammaticality outside of this category occurred for responses attributed to intuition in the look learning condition, where the effect was notably small (β = .08) and was not subsequently replicated in Experiments 2 or 3.

Mean-Relative Familiarity as a Predictor of Confidence

The model predicts that confidence for a given grammaticality judgment should be positively related to the extremity of the familiarity for that string, that is, the absolute difference between the familiarity of the string and the mean familiarity rating for that participant. Each participant's familiarity ratings were *z*-transformed, hereafter referred to as *z-familiarity*. The correlation between confidence and absolute *z*-familiarity was calculated for each participant. Consistent with predictions, the mean correlation was significant ($r = .48$, $SE = .03$), $t(39) = 15.32$, $p < .001$, $d = 2.41$.

Discussion

Experiment 1 evaluated the central claims of the proposed model and found support for each of them. Objective measures of the structural similarity of training and test strings, including fragment measures and repetition structure, predicted participants' subjective familiarity ratings. This provides direct evidence that familiarity ratings reflect learning in an AGL paradigm and have the potential to do so under transfer conditions where repetition structure would be preserved. Familiarity ratings predicted participants' grammaticality judgments, consistent with the proposal that judgments are made relative to the mean of the familiarity distribution. The substantial contribution of grammaticality over and above that of familiarity was apparent only where participants indicated possessing conscious structural knowledge (judgments attributed to rules and memory) derived under deliberate learning conditions. This is consistent with knowledge acquired under the incidental (look) learning condition being derived fairly directly from familiarity; for example, rules may reflect the relative familiarity of certain string fragments. In contrast, deliberate learning appears capable of resulting in knowledge independent of familiarity. Confidence was predicted by the extremity of familiarity ratings, that is, the absolute difference between the familiarity of a string and the mean familiarity. Furthermore, grammaticality judgments made in the absence of confidence (guesses) continued to be predicted by familiarity ratings. This is consistent with accurate guesses being based on differences in familiarity that were too small (at the current level of calibration) to be considered capable of discriminating grammaticality—differences less than the confidence threshold. The calibration process and confidence threshold were explored further in Experiment 2.

Experiment 2

Experiment 2 replicated the key aspects of Experiment 1 and sought to evaluate the proposed calibration process and confidence threshold. Calibration proceeds as participants refine their knowledge of the distribution of familiarity through exposure to test strings. The confidence threshold is the distance between the estimated mean familiarity and that which is considered predictive of grammaticality at the current level of calibration—and hence elicits confidence. Accurate judgments without confidence (guesses) are those based on differences in familiarity less than the confidence threshold. This account makes two predictions: (a) that the confidence threshold will narrow as calibration proceeds and knowledge of the distribution of familiarity is considered more reliable and (b) that participants can differentiate the familiarity of strings within their confidence threshold and hence differentiate their likely

Table 4
Experiment 1: Mean Standardized Coefficients (With Standard Errors) for Grammaticality Judgment Regressed on Familiarity and Grammaticality

		Familiarity		Grammaticality	
Condition	*df*	*M*	*SE*	*M*	*SE*
Look					
Guess	16	.39**	.06	−.01	.07
Intuition	18	.67**	.05	.08*	.03
Rules	8	.62**	.12	.16	.13
Memory	11	.79**	.08	−.09	.10
Rules search					
Guess	15	.45**	.11	.10	.08
Intuition	17	.63**	.06	.08	.07
Rules	12	.29	.18	.50**	.16
Memory	15	.66**	.09	.26*	.11

* $p < .05$. ** $p < .01$.

accuracy despite the absence of confidence. The latter implies that participants possess knowledge that can be strategically exploited to make grammaticality judgments but that is not reflected in confidence reports; this has important implications for the nature of knowledge assessed by the guessing criterion.

The confidence threshold is estimated from the standard deviation of standardized familiarity ratings (z-familiarity) for responses made without confidence. The first prediction is tested by examining the confidence threshold over successive blocks of trials. The second prediction is tested using a variation of a manipulation employed by Twyman and Dienes (in press) to evaluate the guessing criterion. They encouraged half of a group of participants to be more confident, thus reducing the number of guess responses, and evaluated how this affected the mean accuracy of the guesses made. If participants were able to differentiate the likely accuracy of their guess responses, then, when induced to reduce the number of guesses made, they should have retained the least accurate. Confidence encouragement reduced the number of guesses (from 20% to 16% for those making at least one guess) but did not reduce their accuracy. Although this appears inconsistent with participants being able to differentiate the likely accuracy of their guesses, the reduction in guessing achieved by Twyman and Dienes was small. The current study employed a stronger manipulation. The CFM predicts that confidence encouragement will reduce guesses by increasing the perceived reliability of knowledge relating to the distribution of familiarity. This would result in a reduction of both the confidence threshold and the accuracy of guesses made.

Method

Participants

We recruited 160 participants from the University of Sussex library (60 men and 100 women). Participants' ages ranged from 18 to 39 years with a mean age of 22 ($SD = 3.3$). All participants were University of Sussex students and naive to the experimental hypothesis.

Materials

We generated a new random selection of grammar strings using the same grammars and with the same length and balancing constraints as in Experiment 1. The grammar strings used are listed in Appendix B.

Procedure

Training stage. The training procedure was the same as that in Experiment 1 with minor modifications: The order of strings was separately randomized for each participant; the 2-s blank screen between training strings was removed, permitting more exposures in the same training duration; and participants in the incidental learning condition were instructed to repeatedly read each string while they were on the computer screen rather than simply to look at them. As in Experiment 1 there was both an incidental condition and a deliberate (rules-search) condition. The removal of the delay and the change in incidental learning instructions were unsuccessful attempts to increase learning; they did not have a substantial influence and are described here only for completeness.

Test stage. The test procedure for the no-encouragement condition was the same as that in Experiment 1 with two exceptions: The order of test strings was separately randomized for each participant, and the procedure was further automated such that both instructions and responses were given on the computer. Instructions for participants in the confidence encouragement condition were augmented as follows. On-screen instructions for the first string included the following text immediately below the confidence entry box: "Note, most participants are under-confident. Please try to report all of your confidence including the very smallest amounts such as 51% etc." In addition, whenever participants in the confidence encouragement condition provided a confidence rating of less than 65%, the following message was displayed in red below the confidence entry box of the subsequent string: "Your responses so far have been under-confident. Please try to report all of your confidence including the very smallest amounts such as 51% etc." These messages were intended to make participants believe they were in fact being more accurate than their confidence was reflecting and hence encourage them to attribute fewer responses to guessing. The reference to 51% was intended to ensure that even the smallest levels of confidence were reported, with 50% indicating a guess.

Design

A 2 × 2 × 2 × 2 between-participants design was used. This included familiarity (reported vs. unreported), learning (read vs. rules search), and the counterbalanced grammar condition (Grammar A vs. Grammar B) in common with Experiment 1 and an additional confidence condition (encouragement vs. no encouragement). Participants were randomly assigned to learning, grammar, and confidence conditions. Familiarity conditions were run consecutively but close in time and with participants drawn from the same population. All other aspects of the design were the same as in Experiment 1.

Results

We consider results addressing the main aims of Experiment 2 before presenting results replicating those in Experiment 1.

Calibration and the Reduction in Confidence Threshold Over Trials

The mean confidence threshold, as measured by the standard deviation of z-familiarity for guess responses, was contrasted over successive blocks of trials (Trials 1–20 vs. Trials 21–40 vs. Trials 41–60). This revealed a significant linear trend of reducing confidence intervals over successive blocks (Trials 1–20: $M = 0.72$, $SE = 0.05$; Trials 21–40: $M = 0.67$, $SE = 0.04$; Trials 41–60: $M = 0.59$, $SE = 0.04$), $F(1, 45) = 4.29$, $p = .044$, $\eta_p^2 = .16$. This reduction, by confidence condition, is illustrated in Figure 2. Consistent with the proposed calibration process, as participants encountered more test strings they became confident in judging the grammaticality of strings whose familiarity was increasingly close to the mean.

Manipulating Confidence

The effect and interaction of confidence condition (encouragements vs. no encouragement), learning condition (read vs. rules

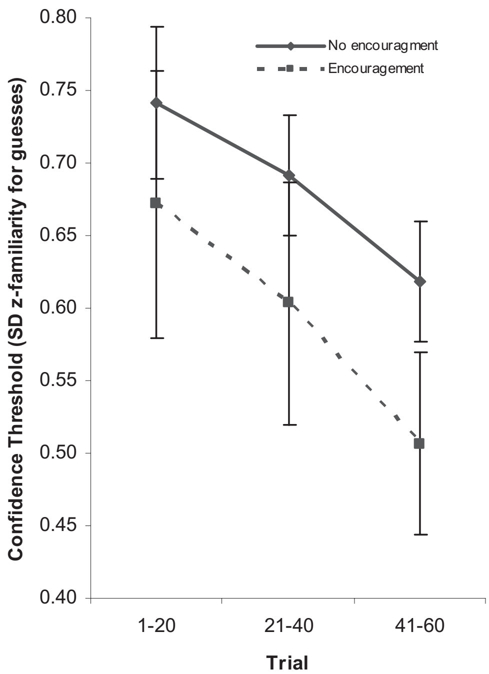

Figure 2. The mean confidence threshold (with standard errors) by trials and confidence condition.

search), and familiarity condition (reported vs. unreported) on the proportion of responses was comprehensively examined with multiple ANOVAs. Those analyses revealed only significant effects relating to confidence condition, each of which is reported below. For the full ANOVAs and descriptive statistics, see Appendix C.

The confidence manipulation was needed to reduce the number of guess responses participants made without eliminating guessing altogether, as only in those cases could the corresponding accuracy be examined. Analysis therefore excluded those participants who made no guess responses (1 participant in the no-encouragement condition and 10 participants in the encouragement condition). The manipulation was effective; the percentage of guess responses made by participants encouraged to be confident (M = 12, SE = 1.3) was significantly less than for those receiving no encouragement (M = 33, SE = 2.1), $t(126.44) = 8.93$, $p < .001$, $d = 1.42$. The difference in the percentage of guess responses between confidence conditions (22%) was substantially greater than that achieved by Twyman and Dienes (in press; 4%). The reduction in guess attributions was accompanied by significant increases in the proportion of both intuition attributions (no encouragement: M = 37, SE = 1.9; encouragement: M = 49, SE = 2.7), $t(128.69) = 3.46$, $p = .001$, $d = 0.58$, and memory attributions (no encouragement: M = 16, SE = 1.5; encouragement: M = 23, SE = 2.5), $t(112.57) = 2.50$, $p = .014$, $d = 0.56$.

The Reduction in Guess Accuracy

Consistent with participants being able to differentiate the likely accuracy of their guess responses, the reduction in proportion of guesses was accompanied by a reduction in their accuracy. The percentage of grammaticality judgments attributed to guessing that were correct was significantly higher in the no-encouragement condition (M = 56, SE = 2.4) than in the encouragement condition (M = 48, SE = 2.4), $t(105.57) = 2.90$, $p = .005$, $d = 0.49$. Consistent with the absence of any significant influence of familiarity condition, the effect was not found to rely on participants being required to report familiarity; participants not providing familiarity ratings similarly showed a significant difference in guessing accuracy (no encouragement: M = 56, SE = 1.9; encouragement: M = 49, SE = 3.3), $t(53.16) = 1.74$, $p = .045$ one-tailed, $d = 0.42$.

In the absence of confidence encouragement, the accuracy of grammaticality judgments attributed to guessing was significantly above that predicted by chance in both the rules-search learning condition (M = 57, SE = 1.8), $t(39) = 4.01$, $p < .001$, $d = 0.63$, and the read condition (M = 55, SE = 1.9), $t(38) = 2.55$, $p = .015$, $d = 0.41$, indicating unconscious judgment knowledge as assessed by the guessing criterion. In contrast, for participants encouraged to be more confident, the accuracy of guesses did not differ significantly from chance in either the rules-search (M = 50, SE = 3.5), $t(34) = 0.12$, $p = .906$, $d = 0.02$, or the read condition (M = 46, SE = 3.5), $t(34) = 1.05$, $p = .300$, $d = -0.18$. Importantly, the difference in accuracy of guess responses was observed despite there being no difference in the total percentage of grammaticality judgments correct between confidence encouragement (M = 61, SE = 1.2) and no-encouragement (M = 60, SE = 1.1) conditions, $t(147) = -0.43$, $p = .666$, $d = 0.07$.

The Effect of Confidence Encouragement on Confidence Thresholds

If participants based their responses on familiarity differences, then confidence encouragement, by implying accuracy, should have increased the perceived reliability of that knowledge. Perceived reliability resulting from confidence encouragement would have the same effect as that resulting from calibration: a reduction in the confidence threshold. That is, participants' guess responses would be restricted to those more tightly clustered around the mean familiarity. Consistent with this prediction the mean confidence threshold, as measured by the *SD* of z-familiarity for guess responses, was significantly narrower in the confidence encouragement condition (M = 0.62, SE = 0.05) than the no-encouragement condition (M = 0.75, SE = 0.02), $t(47.86) = 2.19$, $p = .034$, $d = 0.53$ (see Figure 2). Although this demonstrates that the ability to differentiate the accuracy of guesses was systematically related to differences in subjective familiarity, it need not have been experienced in that way. For example, the larger proportion of memory attributions in the confidence encouragement condition may indicate that some participants experienced greater confidence in recollections. Assuming this to be true, however, those recollections experienced with greater confidence were also those where the familiarity differences were largest.

Structural Similarity Measures as a Predictor of Familiarity

We again evaluated the degree to which the seven structural similarity measures predicted participants' familiarity ratings using multiple regression. Consistent with Experiment 1, the combination of structural similarity measures accounted for a significant proportion

(23%) of the variance in familiarity ratings (adj. $R^2 = .23$, $SE = .02$), $t(79) = 15.15$, $p < .001$, $d = 1.69$. Mean standardized coefficients for each measure are shown in Table 3. In common with Experiment 1, SLP and ARP were significant predictors in their own right. In contrast to Experiment 1, NCP did not reach significance, whereas PACS and ACS did.

Familiarity as a Predictor of Grammaticality Judgments

The mean correlation between familiarity and grammaticality judgment was substantial ($r = .66$, $SE = .02$), $t(79) = 38.27$, $p < .001$, $d = 4.31$, consistent with Experiment 1 ($r = .68$). We again used multiple regression to examine the unique contribution of familiarity and grammaticality to grammaticality judgments for each participant. Mean standardized coefficients by learning condition and decision strategy are given in Table 5.[5] Familiarity contributed to the prediction of grammaticality judgments regardless of learning condition or reported decision strategy. This again included responses attributed to guessing, indicating that familiarity guided responses even in the absence of confidence. The contribution of grammaticality over and above that of familiarity was again consistent with predictions. The only significant contribution occurred where participants' responses reflected the use of conscious structural knowledge (rules and memory attributions) derived after deliberately searching for rules.

Mean-Relative Familiarity as a Predictor of Confidence

The correlation between confidence and absolute *z*-familiarity was again calculated for each participant. The mean correlation was significant ($r = .46$, $SE = .02$), $t(79) = 23.07$, $p < .001$, $d = 2.58$, consistent with the CFM and replicating Experiment 1 ($r = .48$).

Discussion

Participants adopted a narrower confidence threshold as they progressed through the test phase and when they were encouraged to be more confident in their responses. Both effects are consistent with the proposed calibration process: As the perceived reliability of knowledge of the distribution of familiarity increases, so smaller differences from the mean familiarity are taken to reliably predict grammaticality and result in reports of confidence. That small familiarity differences do, on average, predict grammaticality means that adopting a narrower confidence threshold results in fewer accurate guesses. This indicates that under normal circumstances participants possess conscious knowledge that supports accurate grammaticality judgments but which is not recognized as such by participants. This further highlights that the guessing criterion assesses only conscious knowledge of grammaticality and not the conscious status of other knowledge relating to the decision task. Experiment 2 demonstrated that familiarity differences can be exploited to differentiate the likely accuracy of responses normally made without confidence, but it remains unclear if participants are *aware* that their selections reflect differences in familiarity; this was addressed in Experiment 3.

Experiment 2 also replicated all the key findings of Experiment 1: Collectively, the objective measures of the structural similarity between test strings and training strings (including repetition structure) predicted subjective familiarity, subjective familiarity predicted grammaticality judgment, and the familiarity of test strings relative to the mean familiarity predicted confidence. The contribution of grammaticality, controlling for familiarity, was again restricted to judgments made in the presence of conscious structural knowledge derived after deliberate learning. This again supports the proposal that knowledge acquired during implicit learning is largely derived from familiarity, whereas explicit learning can give rise to knowledge of a different nature.

Table 5
Experiment 2: Mean Standardized Coefficients (With Standard Errors) for Grammaticality Judgment Regressed on Familiarity and Grammaticality

Condition	*df*	Familiarity *M*	Familiarity *SE*	Grammaticality *M*	Grammaticality *SE*
Look					
Guess	31	.44**	.07	.00	.08
Intuition	38	.60**	.04	.06	.03
Rules	22	.69**	.06	−.06	.07
Memory	28	.70**	.08	.03	.08
Rules search					
Guess	24	.46**	.06	.04	.05
Intuition	38	.59**	.04	.07	.04
Rules	19	.66**	.07	.20*	.09
Memory	26	.57**	.07	.28**	.07

* $p < .05$. ** $p < .01$.

Experiment 3

Experiments 1 and 2 provided evidence that participants' grammaticality judgments are guided by familiarity, that confidence develops as knowledge of the distribution of familiarity is calibrated, and that differences in familiarity that do not generally support confidence can nonetheless be exploited to make decisions. However, neither experiment has established whether participants are aware of exploiting familiarity as the basis for judgments. Experiment 3 replicated the common elements of Experiments 1 and 2 and directly examined participants' awareness of exploiting familiarity. Three important questions were addressed. First, for what proportion of grammaticality judgments are participants aware of using familiarity as their primary decision strategy? Second, are participants aware of exploiting familiarity to select their responses even when they lack confidence in those judgments? Third, do familiarity ratings continue to predict grammaticality judgments when participants are unaware of exploiting familiarity or any other systematic strategy? Refinements to the way participants reported their confidence and decision strategies were implemented to address these questions.

Firstly, the available options for reported decision strategy were extended to include familiarity, with participants instructed to use this category when they believed they were basing their choice on the familiarity of the string. Secondly, where the instructions for

[5] The same analysis was conducted by confidence encouragement condition and revealed essentially the same results: Familiarity was significant under all attributions in both confidence conditions, and grammaticality reached significance only for memory attributions in the encouragement condition.

Experiments 1 and 2 had implied equivalence between 50% confidence and guessing, Experiment 3 required participants to report their confidence in each judgment independently of the strategy used to make it. This permitted participants to attribute decisions to strategies such as familiarity while reporting having no confidence in their judgment, thus removing any potential temptation to attribute responses to a particular category as a means to reflect a lack of confidence. Finally, the decision strategy *guess* was considered ambiguous in that it could potentially apply to any decision made without confidence. It was therefore replaced with a new category, *random selection*, with participants instructed to use this category only when they believed they were selecting their response at random. In general the reported decision strategies are taken to indicate what participants consider to be their primary source of knowledge. For some categories, participants may also be aware of exploiting other knowledge to a lesser degree. For example, a decision attributed to rules may be based primarily on rules with a lesser contribution of memory. This is not true of all categories however. Random selection, for example, is exclusive, as the use of any other category entails the selection being nonrandom.

Method

Participants

We recruited 80 participants from the University of Sussex library (28 men and 52 women). Participants' ages ranged from 18 to 40 years with a mean age of 22 (SD = 4.0). All participants were University of Sussex students and naive to the experimental hypothesis.

Materials

Experiment 3 used the same training and test strings as Experiment 2 (see Appendix B).

Procedure

Training stage. The training procedure was the same as that in Experiment 1 with the following exceptions: The order of training strings was separately randomized for each participant, and the 2-s blank screen between training strings was removed.

Test stage. The test procedure was the same as that in Experiment 1 with the following minor changes. Participants were required to select from an extended range of decision strategies (random selection, intuition, familiarity, rules, and memory). Instruction for the use of intuition, rule, and memory categories was the same as in Experiments 1 and 2. Participants were instructed to use the random selection category when judgments were thought to be selected completely at random and to use the familiarity category when judgments were thought to be based on feelings of familiarity. Participants were instructed to report their confidence in grammaticality judgments independently of the decision strategy used. Finally, the order of test strings was separately randomized for each participant, and the procedure was fully automated with all instructions and responses given on a computer.

Design

A 2 × 2 × 2 between-participants design was employed with participants randomly assigned to learning (look vs. rules search), familiarity (reported vs. unreported) and grammar (Grammar A vs. Grammar B) conditions. With the exception of changes to the reporting of decision strategies and confidence, as described above, all aspects of the design were the same as in Experiment 1.

Results

The Conscious Use of Familiarity as a Decision Strategy

In all, 77 of the 80 participants reported using familiarity to make grammaticality judgments. Familiarity was the most frequently reported decision strategy, on average accounting for one third of participants' responses (M = 33%, SE = 2.3). A comprehensive ANOVA examining the influence of both learning condition and familiarity condition on the proportion and accuracy of judgments attributed to familiarity and other decision strategies revealed no significant effects (see Appendix C for details). Importantly, use of familiarity did not differ significantly between participants required to report familiarity ratings (M = 34%, SE = 3.2) and those not reporting familiarity ratings (M = 33%, SE = 3.3), $t(78) = 0.25$, $p = .807$, $d = 0.06$. Familiarity was also reported as the basis of grammaticality judgments for one fifth of responses made without confidence (M = 20%, SE = 3.3). Despite the lack of confidence, the familiarity ratings for those judgments were significantly related to grammaticality ($r = .49$, $SE = .16$), $t(10) = 3.00$, $p = .013$, $d = 0.90$, indicating that they did reflect learning. These results indicate that the majority of participants were conscious that their choices reflected differences in familiarity but that they were not always confident that those differences predicted grammaticality. In all 61% (SE = 4.3) of grammaticality judgments made without confidence were reported to be based on decision strategies other than random selection. This confirms that the above-chance performance typically observed in judgments reported without confidence (usually classified as guesses) may result from the conscious application of knowledge, such as familiarity. Participants may be conscious of differences in familiarity and conscious that their responses reflect those differences, but without sufficient calibration they lack conscious knowledge that the differences predict grammaticality.

The Unconscious Influence of Familiarity on Grammaticality Judgments

For decisions attributed to random selection, the bivariate correlation between familiarity and whether a string was endorsed as grammatical was significant ($r = .34$, $SE = .09$), $t(23) = 4.01$, $p = .001$, $d = 0.82$. This indicates that subjective familiarity influenced judgments of grammaticality when participants were unaware of exploiting familiarity, or any systematic strategy, to make their decisions. In the present experiment the familiarity of those responses was not significantly related to the actual grammatical status of the strings ($M = 0.07$, $SE = 0.11$), $t(23) = 0.68$, $p = .501$, $d = 0.14$; hence performance was not reliably different than chance ($M = 51$, $SE = 3.7$), $t(63) = 0.14$, $p = .887$, $d = 0.03$, and there was no unconscious judgment knowledge. Nonetheless, there was evidence of familiarity having an unconscious influence on participants' grammaticality judgments.

Structural Similarity Measures as a Predictor of Familiarity

We again conducted a multiple regression analysis examining the relationship between familiarity and the structural similarity measures. Replicating Experiments 1 and 2, the combination of structural similarity measures accounted for a significant proportion (19%) of the variance in familiarity ratings (adj. $R^2 = .19$, $SE = .02$), $t(39) = 7.71$, $p < .001$, $d = 0.122$. Mean standardized coefficients for each measure are shown in Table 3. Consistent with both Experiments 1 and 2, SLP and ARP were significant predictors in their own right. PACS was also a significant predictor, consistent with Experiment 2.

Familiarity as a Predictor of Grammaticality Judgments

The mean correlation between familiarity and grammaticality judgment was again substantial ($r = .56$, $SE = .03$), $t(39) = 17.66$, $p < .001$, $d = 2.79$, replicating Experiments 1 and 2 ($r = .68$ and $r = .66$, respectively). We again used multiple regression to examine the unique contribution of familiarity and grammaticality to grammaticality judgments for each participant. Mean standardized coefficients by learning condition and decision strategy are given in Table 6. Familiarity significantly predicted grammaticality judgment regardless of decision strategy in the rules-search learning condition and for all except those judgments attributed to random selection in the look learning condition. The contribution of grammaticality, controlling for familiarity, was again consistent with predictions. A significant contribution was apparent only for responses indicating the presence of conscious structural knowledge (in this case rule attributions) made by participants instructed to search for rules during training.

Mean-Relative Familiarity as a Predictor of Confidence

The correlation between confidence and absolute z-familiarity was again calculated for each participant. The mean correlation was significant ($r = .44$, $SE = .03$), $t(39) = 13.08$, $p < .001$, $d = 2.07$, consistent with the model and replicating Experiments 1 and 2 ($r = .48$ and $r = .46$, respectively).

Table 6
Experiment 3: Mean Standardized Coefficients (With Standard Errors) for Grammaticality Judgment Regressed on Familiarity and Grammaticality

		Familiarity		Grammaticality	
Condition	*df*	*M*	*SE*	*M*	*SE*
Look					
Random	11	.07	.13	.14	.09
Familiarity	15	.66**	.06	.01	.07
Intuition	14	.41**	.12	.05	.08
Rules	10	.52**	.11	.06	.10
Memory	8	.65**	.17	−.04	.10
Rules search					
Random	8	.59*	.21	−.28	.23
Familiarity	17	.47**	.10	−.03	.10
Intuition	18	.39**	.08	.09	.08
Rules	11	.49**	.08	.27**	.06
Memory	6	.54**	.12	.13	.10

* $p < .05$. ** $p < .01$.

Discussion

By extending the range of decision strategies to include familiarity, Experiment 3 revealed that participants' consciously exploited familiarity to make a substantial proportion of their grammaticality judgments. Requiring decision strategies to be reported independently of confidence further revealed that participants often used conscious knowledge to make their response without having confidence in their decisions. Consistent with the CFM, participants consciously selected responses based on differences in familiarity which, whilst in fact predictive of grammaticality ($r = .49$), were not considered sufficiently reliable to make that discrimination—as indicated by the absence of confidence. Where familiarity is sufficiently related to grammaticality, its influence can result in accurate responses in the absence of confidence (as seen in Experiments 1 and 2). In such instances participants make accurate judgments while being unaware of knowing whether the strings are grammatical; by definition they have unconscious judgment knowledge. Nonetheless, it is clear from the present experiment that such participants may have conscious knowledge relating to the decision process, that is, that familiarity was used (even if they do not know the basis of such familiarity; cf. Norman, Price, & Duff, 2006; Norman et al., 2007). This highlights the need for precision in specifying the contents of knowledge states measured as being unconscious and clarifies the limitation of confidence-based measures when used alone. Finally, the experiment also found evidence that familiarity can exert an influence on participants' grammaticality judgments apparently without their awareness; familiarity predicted responses that were reported as being selected at random, albeit without resulting in above-chance accuracy in those instances.

The central aspects of the proposed model examined in Experiments 1 and 2 were also replicated: Structural similarity measures, including repetition structure, reliably predicted familiarity; familiarity predicted grammaticality judgment; mean-relative familiarity predicted confidence; and, controlling for familiarity, grammaticality predicted only grammaticality judgments for responses indicating the presence of conscious structural knowledge made by participants instructed to search for rules during training.

General Discussion

The Calibrated Familiarity Model of AGL

The objective of the present study was to evaluate by direct means a detailed model of artificial grammar learning (AGL) based on subjective familiarity. The results provide multiply-replicated evidence for the proposed model. All three experiments found that objective similarity measures predicted familiarity ratings (mean $R = .45$), that familiarity ratings predicted grammaticality judgments (mean $r = .64$), that the extremity of familiarity ratings (absolute z-familiarity) predicted confidence (mean $r = .46$), and that substantial knowledge distinct from familiarity was exploited only where participants demonstrated conscious structural knowledge acquired during deliberate learning. Experiment 2 further demonstrated that confidence developed through the process of calibration as knowledge of the distribution of familiarity increased and that differences in familiarity could be exploited prior to their being considered predictive of grammaticality. Finally, Experiment 3 demonstrated that participants were often conscious that their choices reflected differences in familiarity, that this often included instances where they had no confidence in the resulting judgment, and that familiarity could also influence responding in the absence of awareness.

The results concur with a wealth of evidence that has inferred a role of familiarity by indirect means (Kinder & Assmann, 2000; Kinder et al., 2003; Knowlton & Squire, 1996; Lotz & Kinder, 2006; Meulemans & Van der Linden, 1997; Servan Schreiber & Anderson, 1990) and provide decisive evidence that familiarity is the essential source of knowledge in implicit learning of artificial grammars. The model explains classification performance under standard and transfer conditions, clarifies the nature of knowledge judged to be unconscious by the guessing criterion, and explicates the process by which conscious judgment knowledge develops. Furthermore, the findings provide evidence for a dual-process account of implicit and explicit learning that can account for the differential strengths and susceptibilities of those mechanisms.

The Basis of Subjective Familiarity in AGL

Objective measures of the structural similarity between training and test strings on average accounted for 21% of the variance in familiarity ratings. The relationship was significant in all three experiments and provides evidence that in AGL feelings of familiarity represent learning. The failure of similarity measures to fully predict familiarity ratings is both predictable and consistent with their prior failure to fully account for grammaticality judgments (Higham, 1997; Meulemans & Van der Linden, 1997; Vokey & Brooks, 1992). No simple set of statistical measures can be expected to encapsulate this highly developed feature of human memory, hence the importance of examining reports of these feelings directly when attempting to establish the scope of their influence in AGL. The contribution of structural similarity to subjective feelings of familiarity does not of course preclude the contribution of other factors, for example, the manner in which stimuli are encoded and subsequently processed, as elegantly demonstrated by Whittlesea and Wright (1997). Manipulations of prime duration have also been shown to produce illusions of familiarity and recollection, indicating that sources other than structural similarity may contribute to both (Higham & Vokey, 2004).

Consistent with expectations, significant individual predictors of familiarity included measures of both fragment frequency and repetition structure. The contribution of repetition structure provides direct evidence that feelings of familiarity have the potential to account for transfer performance. Similarity in repetition structure has been shown to be the primary source of classification accuracy in transfer conditions (Brooks & Vokey, 1991; Gomez, Gerken, & Schvaneveldt, 2000; Mathews & Roussel, 1997). The current study provides the first direct evidence that these similarities are experienced as familiarity.

The relationship between familiarity and structural similarity is also, in principle, consistent with the purported contribution of fluency in AGL (Buchner, 1994; Kinder et al., 2003). The structural similarity of test strings could in theory enhance their fluency which in turn could be experienced as familiarity. Although this is the natural assumption, there are reasons to question this account. Using word stimuli rather than artificial grammars, Whittlesea and Leboe (2000) demonstrated that classification judgments can be based on a number of different heuristics they call fluency, generation, and resemblance. The effect of manipulating processing fluency in AGL was subsequently examined by Kinder et al. (2003), who concluded that fluency was the default mechanism for grammaticality classifications. However, in a series of experiments examining the influence of both naturally occurring and manipulated differences in fluency, Scott and Dienes (2008) found fluency to have only a very weak influence on responding as contrasted with that of subjective familiarity. Furthermore, with counterbalanced stimuli, contrary to Buchner (1994), naturally occurring differences in fluency were found not to be related to grammaticality and as such could not be the basis of accurate classifications.

Familiarity and Judgment Knowledge in AGL

Judgment knowledge in AGL is knowledge of whether or not a given string is grammatical. The guessing criterion assesses the conscious status of this knowledge by examining participants' confidence in discriminating grammaticality. Accurate judgments made in the absence of any confidence are taken to indicate unconscious judgment knowledge. However, while confidence in a grammaticality judgment may accurately assess the conscious status of knowing that the string is grammatical, it does not assess the conscious status of all knowledge relating to the decision process. The present study provided a more comprehensive assessment of conscious knowledge relating to grammaticality judgments. All three studies found that grammaticality judgments were systematically related to subjective reports of familiarity, even when judgments were made without confidence. Experiment 3 further showed that participants were often aware that their choices reflected differences in familiarity.

Critics of subjective measures have argued that participants may not report all their confidence and that a spurious assessment of unconscious knowledge may result (Dulany et al., 1984; Reingold & Merikle, 1990; Shanks & St. John, 1994). Accurate performance in the apparent absence of confidence is attributed to participants choosing not to report confidence despite experiencing it. While it is not possible to disprove this account, we provide an alternative that does not require the assumption that participants deliberately report one thing while thinking another. The account we present relies on distinguishing different conscious states involved in the decision process, for example, separating conscious knowledge of whether or not a string is grammatical from conscious knowledge that it feels more or less familiar. The findings indicate that for some responses participants experience familiarity differences, and consciously use those differences when selecting a response, but lack meta-knowledge (and hence confidence) that the differences support accurate grammaticality judgments. Rather than confidence always being present and participants' reports being disingenuous, conscious knowledge may influence responding in the absence of confidence.

Experiment 2 demonstrated that confidence, and hence conscious judgment knowledge, emerged as participants refined their knowledge of the distribution of familiarity. Exposure to more strings or feedback implying accuracy both resulted in a narrowing of the confidence threshold, that is, a reduction in the amount a string's familiarity needed to differ from the mean for participants to report confidence in judging grammaticality. These findings support the proposed calibration process; confidence develops as the perceived reliability of knowledge relating to familiarity increases. Whittlesea and Dorken (1997) argued that the failure to report conscious knowledge as confidence may result from the absence of meta-knowledge that the knowledge used is relevant to the classification judgment. The calibration process evaluated in the current study provides an account of how that meta-knowledge develops.

Could there be occasions when people make systematically correct judgments without being conscious of employing a strategy, familiarity or otherwise? The current study provides no evidence for this; in Experiment 3, where participants attributed responses to random selection, their performance was at chance. Other studies have found this effect, however. Scott and Dienes (2008) conducted four studies employing the same set of decision strategies and consistently found above-chance performance in responses attributed to random selection. Furthermore, whereas responses attributed to random selection in the current study did not show above-chance accuracy, they were still significantly predicted by familiarity ratings. Participants experienced differences in the familiarity of the strings, as reflected in their familiarity ratings, but for those attributed to random selection they were apparently unaware that the familiarity differences influenced their choices.

Results from another commonly used implicit learning paradigm are also consistent with an unconscious influence of familiarity. Fu, Fu, and Dienes (2008, their Experiment 2) found that after training on a serial reaction time task, people asked to generate a sequence different from that seen during training nonetheless generated the training sequence at above baseline levels (cf. Destrebecqz & Cleeremans, 2001; Wilkinson & Shanks, 2004). When people were trained on a deterministic sequence, rewarding people for correct responses eliminated the above-baseline generation. However, when the training sequence was noisy, people still generated the training sequence at above baseline levels even when there were cash rewards for not doing so. This is again consistent with familiarity influencing responses without participants' awareness; the familiarity of sequence elements may have caused participants to generate them unwittingly. Both experimental paradigms suggest that low levels of familiarity may result in a systematic bias in responding without participants' awareness. However, a systematic bias does not permit strategic responding. Although its existence likely reflects a general utility in our evolutionary history, whether it helps or hinders performance in any given task will be unrelated to an individual's objectives (Jacoby, 1991).

Familiarity and Structural Knowledge in AGL

Judgment knowledge tells us whether a given string is grammatical. Structural knowledge tells us which features indicate its grammaticality, for example, the presence or absence of particular fragments or conformance to a particular repetition structure. According to Norman et al. (2006), judgments made in implicit learning tasks are generally accompanied by some conscious feelings, such as familiarity, rightness, or goodness, which they call "fringe" feelings. The feelings are based on and indicate the presence of structural knowledge but do not in themselves make the structural knowledge conscious (Dienes & Scott, 2005). Familiarity may be based on unconscious structural knowledge, for example, knowledge embedded in the synaptic strengths of a neural network, while still giving rise to conscious judgment knowledge.

The reporting of decision strategy in the current study provided the means to differentiate judgments according to the presence or absence of conscious structural knowledge. The predictors of grammaticality judgment depending on learning intention and the status of structural knowledge conformed to expectations. Under the incidental learning condition, familiarity was the only substantial predictor of grammaticality judgments regardless of the status of structural knowledge. In contrast, under deliberate learning instructions, in the presence of conscious structural knowledge (as indicated by the reported use of rules or recollective memory) there was a significant independent contribution of grammaticality.

We account for these differences based on when and how the conscious structural knowledge might be derived. We hold that after incidental learning, participants derive conscious structural knowledge during the test phase guided directly by the differential familiarity of grammatical and ungrammatical strings (cf. Frensch et al., 2003; Mathews, Buss, Stanley, & Blanchard Fields, 1989), for example, basing rules on fragments common to the most familiar or unfamiliar strings. In contrast, during deliberate learning participants also derive structural knowledge during training. Hypothesized rules will consequently be less directly related to the familiarity of the test strings.

This account has the potential to explain both the differential susceptibility of implicit and explicit learning to attentional demands and why under some circumstances deliberate attempts to learn may actually impede performance. Dienes and Scott (2005) found that divided attention during training reduced the accuracy of judgments attributed to rules and memory under deliberate but not incidental learning conditions. It is plausible that divided attention reduces the resources available to hypothesize about rules without significantly affecting the development of familiarity. Under such circumstances structural knowledge derived during deliberate but not incidental learning would be affected. Destrebecqz and Cleeremans (2001) presented evidence of a similar effect in the SRT, suggesting that it is not peculiar to AGL. They limited the stimulus processing by removing the delay between stimuli and similarly observed results, consistent with a reduction in the development of explicit representations. Also see Dienes and Fahey (1998) for evidence relevant to the use of familiarity in the dynamic control tasks.

Reber and Lewis (1977) demonstrated that for some grammars deliberate learning resulted in fewer accurate classifications than incidental learning. During deliberate learning, participants attempt to derive rules during training, whereas in implicit learning this can occur only during testing. Given that rules derived during training cannot be guided by the differential familiarity of grammatical and ungrammatical strings, they will likely include more inaccurate inferences. This predicts that where a grammar is complex, consistent with Reber and Lewis's findings, deliberate attempts to learn may impede performance.

A Multiple-System Account of Implicit and Explicit Learning

The proposed account is in accord with definitions provided by Hayes and Broadbent (1988), who described implicit learning as an "unselective and passive aggregation of information about the co-occurrence of environmental events and features" (p. 251) and saw explicit learning as being guided by hypothesis testing. As such, it is consistent with multiple-system views of implicit and explicit learning (e.g., Berry & Dienes, 1993; Curran & Keele, 1993; Jimenez & Vazquez, 2005; Willingham & Goedert

Eschmann, 1999). In contrast, single-system accounts hold that one mechanism underlies the knowledge derived from both implicit and explicit learning (e.g., Destrebecqz & Cleeremans, 2003; Shanks, Wilkinson, & Channon, 2003).

Destrebecqz and Cleeremans (2003) argued that as learning proceeds, the representations formed become more stable and of better quality. Representations below a certain quality are capable of influencing behavior while not yet being able to support conscious awareness. Our account is largely consistent with this proposal. Familiarity differences may initially influence responding (even without awareness), but only as knowledge of the distribution of familiarity is refined does conscious judgment knowledge emerge. Fu et al. (2008) similarly showed that unconscious judgment knowledge was detectable given a shorter rather than a longer period of training. However, Destrebecqz and Cleeremans's account does not address the apparent development of conscious structural knowledge by an alternative route under explicit learning conditions, that which we postulate to result from hypothesizing about rules.

Shanks et al. (2003) proposed a single-system model that is based entirely on familiarity. They account for the apparent dissociations between measures of implicit and explicit knowledge as resulting from access to this single knowledge source being subject to independent errors. Independent error terms would make it possible for familiarity-based knowledge to result in accurate grammaticality judgments while failing to result in accurate familiarity ratings, creating a spurious contribution of grammaticality over and above familiarity. However, an account based on independent errors would not predict, a priori, that grammaticality should make a systematically larger contribution to only those responses attributed to rules and memory and made only under deliberate learning conditions. More generally, in these cases people claim to no longer be relying on a unidimensional output but have a richer content available to them (Gardiner, Ramponi, & Richardson Klavehn, 1998).

Conclusion

The results of the experiments presented here reveal the essential role played by subjective familiarity in AGL and clarify the extent and nature of conscious knowledge in that paradigm. Supporting the CFM, the findings endorse a dual-process account of implicit learning and explicate the mechanism by which conscious judgment knowledge develops. Familiarity has been shown to support a powerful learning mechanism capable of accounting for the entirety of knowledge acquired in implicit learning of artificial grammars, though insufficient to account for all the knowledge acquired in explicit learning.

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Appendix A

Training and Test Strings Used in Experiment 1

Training strings		Test strings	
Grammar A	Grammar B	Grammar A	Grammar B
XMMXM	XXRRM	VTVTM	VTRRM
XXRVTM	VVRXRM	XXRVM	XMTRM
VVTRVM	XXRRRM	VTTTVM	VTRRRM
VTTTTVM	VTRRRRM	VTTVTM	VVRMTM
XMMMMXM	VVTRXRM	XMMMXM	XMTRRM
XXRTVTM	XMVTRXM	XMXRVM	XMVRXM
XMXRTVTM	VVRXRRRM	VTTTVTM	VVRMTRM
XXRTTTVM	VVTRXRRM	VTVTRVM	VVRXRRM
XMMXRTVM	XMVRMTRM	VVTRVTM	VVTRMTM
VTVTRVTM	XMVTRMTM	XMMXRVM	XMTRRRM
VVTRTTVTM	VVTTTRMTM	XMXRTVM	XMVRMTM
VTTTVTRVM	VVTTTRXRM	XXRTTVM	XMVRXRM
XMXRTTTVM	XMVRMTRRM	VTTTTVTM	VTRRRRRM
XMMMXRVTM	XMVTRMTRM	VTTVTRVM	VVRMTRRM
XMMMXRTVM	XMVTTRMTM	VTVTRTVM	VVRMVRXM
		VVTRTVTM	VVTTRMTM
		XMMMXRVM	VVTTRXRM
		XMXRTTVM	XMVRXRRM
		XXRTTVTM	XMVTRXRM
		XXRVTRVM	XMVTTRXM
		VTTTVTRVM	VVRMVRXRM
		VTTVTRTVM	VVRMVTRXM
		VTVTRTTVM	VVTRMTRRM
		VTVTRTVTM	VVTRMVRXM
		VVTRTTVTM	VVTRXRRRM
		XMMXRTTVM	VVTTRMTRM
		XMXRTTVTM	VVTTRXRRM
		XMXRVTRVM	XMVRMVRXM
		XXRTTTVTM	XMVRXRRRM
		XXRTVTRVM	XMVTRXRRM

Appendix B

Training and Test Strings Used in Experiments 2 and 3

Training strings		Test strings	
Grammar A	Grammar B	Grammar A	Grammar B
XMMXM	XMTRM	VTVTM	VTRRM
VTTVTM	VVRMTM	XXRVM	XXRRM
XMXRVM	XMTRRM	XMMMXM	VVRXRM
VVTRTVM	VTRRRRM	XXRTVM	VVTRXM
XXRTTVM	XMVTRXM	XXRVTM	XMVRXM
VTTTTVM	VVTRXRM	VVTRVM	XXRRRM
XMMXRTVM	VVTRXRRM	VTTTVTM	XMVRXRM
XMMMXRVM	XMTRRRRM	XMMMMXM	VVTTRXM
VVTRTTVM	XMVRMTRM	VVTRVTM	XMVRMTM
XMXRTVTM	VVTTRXRM	XXRTVTM	XXRRRRM
XMXRVTRVM	VVRMVRXRM	XMXRVTM	VVRMTRM
XXRVTRTVM	XXRRRRRRM	XMMXRVM	VVRXRRM
VVTRVTRVM	VVTTTTRXM	XMXRTTVM	XXRRRRRM
XMXRTTTVM	VVTTTRMTM	VTTVTRVM	VVTTTRXM
XMMXRTVTM	VTRRRRRRM	VTVTRTVM	VTRRRRRM
		XMMMMMXM	VVTRMTRM
		VTTTTVTM	XMVTRMTM
		XXRVTRVM	VVRMTRRM
		VTVTRVTM	VVTTRMTM
		VTTTTTVTM	XMVTRMTRM
		VTTVTRTVM	VVTTTRXRM
		XMMXRTTVM	XMVRMVRXM
		VTVTRTVTM	XMVRMTRRM
		XMMMMMMXM	VVTRMVRXM
		VTTTVTRVM	VVTRXRRRM
		VVTRTTVTM	VVTRMTRRM
		VTTTTTTVM	XMVTTTRXM
		XXRTTTTVM	VVTTRXRRM
		XXRTVTRVM	VVRXRRRRM

Appendix C

Analyses of Variance and Accompanying Descriptive Statistics

Table C1

Experiment 1: 2 × 2 × 4 Mixed ANOVA on Percentage of Correct Grammaticality Judgments With Learning Condition (Look vs. Rules Search), Familiarity Condition (Reported vs. Unreported), and Decision Strategy (Guess vs. Intuition vs. Rules vs. Memory) as Independent Variables

Source	*df*	*F*	η_p^2
Between participants			
Learning condition (L)	1	5.42*	.12
Familiarity condition (F)	1	0.66	.02
L × F	1	0.49	.01
Error	39	(819.45)	
Within participants			
Decision strategy (DS)	3	7.24**	.16
DS × L	3	1.42	.04
DS × F	3	1.75	.04
DS × L × F	3	1.04	.03
Error (DS)	117	(326.84)	

Note. Values in parentheses represent mean square errors. Descriptive Statistics are reported in Table C2. ANOVA = analysis of variance.
* $p < .05$. ** $p < .01$.

(*Appendixes continue*)

Table C2
Experiment 1: Mean Percentage Correct for Analysis of Variance Reported in Table C1

Condition	*N*	Decision strategy			
		Guess	Intuition	Rules	Memory
Look					
Familiarity reported	10	48 (5.4)	63 (2.7)	51 (8.9)	62 (12)
Familiarity unreported	11	44 (6.8)	61 (5.0)	74 (7.0)	71 (7.1)
Total	21	46 (4.3)	62 (2.8)	63 (6.1)	66 (6.7)
Rules search					
Familiarity reported	12	62 (5.6)	65 (5.5)	74 (7.5)	75 (3.9)
Familiarity unreported	10	64 (6.1)	61 (4.5)	77 (5.3)	77 (5.8)
Total	22	63 (4.0)	63 (3.6)	75 (4.6)	76 (3.3)
Total					
Familiarity reported	22	56 (4.1)	64 (3.2)	64 (6.2)	69 (5.9)
Familiarity unreported	21	54 (5.0)	61 (3.3)	75 (4.3)	74 (4.6)
Total	43	55 (3.2)	63 (2.3)	69 (3.9)	71 (3.7)

Note. Values in parentheses represent standard error of the mean.

Table C3
Experiment 1: 2 × 2 Between-Participants ANOVAs on Percentage of Responses With Learning Condition (Look vs. Rules Search) and Familiarity Condition (Reported vs. Unreported) as Independent Variables

Decision strategy	*df*	*F*	η_p^2
Guess			
Learning condition (L)	1	4.72	.06
Familiarity condition (F)	1	0.00	.00
L × F	1	0.04	.00
Error	76	(353.22)	
Intuition			
Learning condition (L)	1	4.58	.06
Familiarity condition (F)	1	4.05	.05
L × F	1	0.24	.00
Error	76	(404.18)	
Rules			
Learning condition (L)	1	9.75*	.11
Familiarity condition (F)	1	0.13	.00
L × F	1	0.80	.01
Error	76	(327.01)	
Memory			
Learning condition (L)	1	2.70	.03
Familiarity condition (F)	1	4.09	.05
L × F	1	0.35	.00
Error	76	(277.96)	

Note. Values in parentheses represent mean square errors. Analyses of variance (ANOVAs) were conducted separately for each decision strategy. Descriptive statistics are reported in Table C4.
* $p < .05$, applying Hochberg's (1988) sequential Bonferroni, controlling familywise error over decision strategy.

Table C4
Experiment 1: Mean Percentage of Responses for Analyses of Variance Reported in Table C3

		Decision strategy			
Condition	*N*	Guess	Intuition	Rules	Memory
Look					
Familiarity reported	20	28 (4.4)	49 (5.5)	7 (1.9)	16 (3.1)
Familiarity unreported	20	29 (4.8)	37 (4.4)	13 (3.7)	21 (3.7)
Total	40	29 (3.2)	43 (3.6)	10 (2.1)	18 (2.4)
Rules search					
Familiarity reported	20	20 (3.0)	37 (4.0)	24 (4.2)	20 (3.4)
Familiarity unreported	20	19 (4.4)	30 (3.9)	22 (5.5)	29 (4.5)
Total	40	19 (2.6)	34 (2.8)	23 (3.4)	25 (2.9)
Total					
Familiarity reported	40	24 (2.7)	43 (3.5)	16 (2.6)	18 (2.3)
Familiarity unreported	40	24 (3.3)	34 (3.0)	17 (3.3)	25 (2.9)
Total	80	24 (2.1)	38 (2.3)	16 (2.1)	21 (1.9)

Note. Values in parentheses represent standard error of the mean.

Table C5
Experiment 2: 2 × 2 × 2 × 4 Mixed ANOVA on Percentage of Correct Grammaticality Judgments With Learning Condition (Look vs. Rules Search), Confidence Condition (Encouragement vs. No Encouragement), Familiarity Condition (Reported vs. Unreported), and Decision Strategy (Guess vs. Intuition vs. Rules vs. Memory) as Independent Variables

Source	*df*	*F*	η_p^2
Between participants			
Learning condition (L)	1	4.34*	.05
Confidence condition (C)	1	0.44	.01
Familiarity condition (F)	1	0.03	<.001
L × C	1	0.01	<.001
L × F	1	0.94	.01
C × F	1	1.12	.01
L × C × F	1	1.22	.01
Error	88	(558.05)	
Within participants			
Decision strategy (DS)	3	24.13**	.22
DS × L	3	0.51	.01
DS × C	3	4.87**	.05
DS × F	3	0.32	<.01
DS × L × C	3	1.31	.02
DS × L × F	3	1.28	.01
DS × C × F	3	0.26	<.01
DS × L × C × F	3	1.61	.02
Error (DS)	264	(262.68)	

Note. Values in parentheses represent mean square errors. Descriptive statistics are reported in Table C6. ANOVA = analysis of variance.
* $p < .05$. ** $p < .01$.

(*Appendixes continue*)

Table C6
Experiment 2: Mean Percentage Correct for Analysis of Variance Reported in Table C5

		Decision strategy			
Condition	*N*	Guess	Intuition	Rules	Memory
Confidence encouragement					
Read					
Familiarity reported	16	50 (6.4)	55 (2.5)	63 (3.9)	64 (3.8)
Familiarity unreported	8	42 (5.0)	57 (4.1)	68 (6.4)	76 (6.1)
Total	24	47 (4.6)	56 (2.1)	65 (3.3)	68 (3.4)
Rules search					
Familiarity reported	10	51 (7.3)	69 (3.8)	72 (6.2)	82 (7.4)
Familiarity unreported	10	51 (7.6)	58 (2.0)	63 (5.0)	72 (6.2)
Total	20	51 (5.1)	63 (2.5)	67 (4.0)	77 (4.8)
Total					
Familiarity reported	26	50 (4.7)	60 (2.5)	66 (3.4)	71 (4.0)
Familiarity unreported	18	47 (4.8)	57 (2.1)	65 (3.9)	74 (4.3)
Total	44	49 (3.4)	59 (1.7)	66 (2.5)	72 (2.9)
No confidence encouragement					
Read					
Familiarity reported	9	54 (4.7)	53 (4.3)	51 (6.8)	67 (9.3)
Familiarity unreported	15	57 (2.5)	59 (4.1)	46 (5.6)	76 (4.3)
Total	24	56 (2.3)	57 (3.0)	48 (4.3)	72 (4.3)
Rules search					
Familiarity reported	14	57 (3.0)	59 (4.9)	57 (5.4)	71 (6.9)
Familiarity unreported	14	55 (3.4)	66 (3.4)	66 (4.7)	72 (8.1)
Total	28	56 (2.2)	62 (3.0)	62 (3.6)	71 (5.2)
Total					
Familiarity reported	23	56 (2.5)	57 (3.4)	55 (4.2)	70 (5.4)
Familiarity unreported	29	56 (2.0)	62 (2.7)	56 (4.1)	74 (4.4)
Total	52	56 (1.6)	60 (2.1)	55 (2.9)	72 (3.4)
Total					
Read					
Familiarity reported	25	51 (4.4)	54 (2.2)	59 (3.6)	65 (4.0)
Familiarity unreported	23	52 (2.7)	58 (3.0)	54 (4.7)	76 (3.4)
Total	48	52 (2.6)	56 (1.8)	56 (2.9)	70 (2.7)
Rules search					
Familiarity reported	24	55 (3.5)	63 (3.4)	63 (4.3)	76 (5.1)
Familiarity unreported	24	53 (3.6)	62 (2.2)	65 (3.4)	72 (5.3)
Total	48	54 (2.5)	63 (2.0)	64 (2.7)	74 (3.6)
Total					
Familiarity reported	49	53 (2.8)	59 (2.1)	61 (2.8)	70 (3.3)
Familiarity unreported	47	52 (2.3)	60 (1.9)	59 (3.0)	74 (3.2)
Total	96	53 (1.8)	59 (1.4)	60 (2.0)	72 (2.3)

Note. Values in parentheses represent standard error of the mean.

Table C7
Experiment 2: 2 × 2 × 2 Between-Participants ANOVAs on Percentage of Responses With Learning Condition (Look vs. Rules Search), Familiarity Condition (Reported vs. Unreported), and Confidence Condition (Encouragement vs. No Encouragement) as Independent Variables

Decision strategy	*df*	*F*	η_p^2
Guess			
Learning condition (L)	1	0.27	.00
Familiarity condition (F)	1	0.45	.00
Confidence condition (C)	1	87.35*	.36
F × L	1	0.05	.00
F × C	1	0.60	.00
L × C	1	1.14	.01
F × L × C	1	0.01	.00
Error	152	(233.55)	
Intuition			
Learning condition (L)	1	0.01	.00
Familiarity condition (F)	1	0.00	.00
Confidence condition (C)	1	19.28*	.11
F × L	1	0.11	.00
F × C	1	0.36	.00
L × C	1	0.96	.01
F × L × C	1	0.36	.00
Error	152	(441.31)	
Rules			
Learning condition (L)	1	2.80	.02
Familiarity condition (F)	1	0.14	.00
Confidence condition (C)	1	0.06	.00
F × L	1	1.62	.01
F × C	1	0.09	.00
L × C	1	0.03	.00
F × L × C	1	1.82	.01
Error	152	(316.66)	
Memory			
Learning condition (L)	1	5.63	.04
Familiarity condition (F)	1	1.07	.01
Confidence condition (C)	1	7.56*	.05
F × L	1	1.32	.01
F × C	1	0.13	.00
L × C	1	0.00	.00
F × L × C	1	4.30	.03
Error	152	(281.42)	

Note. Values in parentheses represent mean square errors. Analyses of variance (ANOVAs) were conducted separately for each decision strategy. Descriptive statistics are reported in Table C8.
* $p < .05$, applying Hochberg's (1988) sequential Bonferroni, controlling familywise error over decision strategy.

(*Appendixes continue*)

Table C8
Experiment 2: Mean Percentage of Responses for Analyses of Variance Reported in Table C7

		Decision strategy			
Condition	*N*	Guess	Intuition	Rules	Memory
No encouragement					
Read					
No familiarity	20	29 (3.5)	39 (3.2)	8 (1.9)	24 (2.8)
Familiarity	20	33 (4.2)	38 (4.2)	16 (5.1)	14 (3.0)
Total	40	31 (2.7)	38 (2.6)	12 (2.8)	19 (2.2)
Rules search					
No familiarity	20	33 (4.6)	37 (4.8)	21 (4.3)	9 (2.2)
Familiarity	20	36 (4.4)	34 (3.5)	14 (4.0)	16 (2.7)
Total	40	35 (3.2)	35 (2.9)	17 (2.9)	13 (1.8)
Total					
No familiarity	40	31 (2.9)	38 (2.8)	15 (2.5)	17 (2.1)
Familiarity	40	34 (3.0)	36 (2.7)	15 (3.2)	15 (2.0)
Total	80	33 (2.1)	37 (2.0)	15 (2.0)	16 (1.5)
Encouragement					
Read					
No familiarity	20	10 (3.2)	50 (5.9)	13 (3.5)	27 (4.8)
Familiarity	20	11 (1.6)	49 (4.5)	14 (2.9)	26 (3.5)
Total	40	11 (1.8)	50 (3.7)	13 (2.2)	26 (2.9)
Rules search					
No familiarity	20	10 (1.9)	51 (4.3)	17 (3.9)	23 (5.6)
Familiarity	20	9 (2.5)	56 (6.3)	19 (5.2)	17 (4.1)
Total	40	9 (1.6)	53 (3.8)	18 (3.2)	20 (3.5)
Total					
No familiarity	40	10 (1.9)	50 (3.6)	15 (2.6)	25 (3.6)
Familiarity	40	10 (1.5)	52 (3.9)	16 (3.0)	21 (2.8)
Total	80	10 (1.2)	51 (2.6)	16 (2.0)	23 (2.3)
Total					
Read					
No familiarity	40	20 (2.8)	44 (3.4)	11 (2.0)	25 (2.7)
Familiarity	40	22 (2.8)	43 (3.2)	15 (2.9)	20 (2.5)
Total	80	21 (2.0)	44 (2.3)	13 (1.8)	22 (1.9)
Rules search					
No familiarity	40	22 (3.1)	44 (3.4)	19 (2.9)	16 (3.2)
Familiarity	40	23 (3.3)	45 (4.0)	16 (3.2)	16 (2.4)
Total	80	22 (2.3)	44 (2.6)	18 (2.2)	16 (2.0)
Total					
No familiarity	80	21 (2.1)	44 (2.4)	15 (1.8)	21 (2.1)
Familiarity	80	22 (2.2)	44 (2.5)	16 (2.2)	18 (1.7)
Total	160	21 (1.5)	44 (1.7)	15 (1.4)	19 (1.4)

Note. Values in parentheses represent standard error of the mean.

Table C9
Experiment 3: 2 × 2 × 5 Mixed ANOVA on Percentage of Correct Grammaticality Judgments With Learning Condition (Look vs. Rules Search), Familiarity Condition (Reported vs. Unreported), and Decision Strategy (Random Selection vs. Intuition vs. Familiarity vs. Rules vs. Memory) as Independent Variables

Source	*df*	*F*	η_p^2
Between participants			
Learning condition (L)	1	<0.001	<.001
Familiarity condition (F)	1	0.31	.01
L × F	1	1.53	.05
Error	28	(595.29)	
Within participants			
Attribution (A)	3.85	0.33	.01
A × L	3.85	1.13	.04
A × F	3.85	0.84	.03
A × L × F	3.85	1.00	.03
Error (A)	107.84	(630.44)	

Note. Values in parentheses represent mean square errors. There were no significant effects. Mauchly's test of sphericity was significant so results are reported with Huynh–Feldt corrected *df* and significance values. Descriptive statistics are reported in Table C10. ANOVA = analysis of variance.

Table C10
Experiment 3: Mean Percentage Correct for Analysis of Variance Reported in Table C9

		Decision strategy				
Condition	*N*	Random	Familiarity	Intuition	Rules	Memory
Look						
Familiarity reported	9	41 (10)	64 (5.5)	49 (6.7)	50 (8.2)	52 (8.9)
Familiarity unreported	6	51 (13.2)	53 (5.7)	68 (7.9)	52 (5.2)	69 (13.2)
Total	15	45 (7.8)	60 (4.2)	56 (5.5)	51 (5.2)	59 (7.5)
Rules search						
Familiarity reported	10	50 (11.1)	61 (5.7)	51 (5.2)	59 (6.1)	59 (8.6)
Familiarity unreported	7	67 (13.3)	57 (7.1)	45 (2.6)	53 (11.4)	45 (11.6)
Total	17	57 (8.5)	59 (4.4)	49 (3.2)	57 (5.7)	53 (7.0)
Total						
Familiarity reported	19	46 (7.4)	63 (3.9)	50 (4.1)	55 (5.0)	56 (6.1)
Familiarity unreported	13	60 (9.3)	55 (4.5)	56 (4.9)	53 (6.3)	56 (9.0)
Total	32	52 (5.8)	59 (3.0)	52 (3.1)	54 (3.9)	56 (5.1)

Note. Values in parentheses represent standard error of the mean.

Table C11
Experiment 3: 2 × 2 Between-Participants ANOVAs on Percentage of Responses With Learning Condition (Look vs. Rules Search) and Familiarity Condition (Reported vs. Unreported) as Independent Variables

Decision strategy	*df*	*F*	η_p^2
Random			
Learning condition (L)	1	0.03	.00
Familiarity condition (F)	1	1.23	.02
L × F	1	3.05	.04
Error	76	(213.90)	
Familiarity			
Learning condition (L)	1	0.06	.00
Familiarity condition (F)	1	2.71	.03
L × F	1	1.20	.02
Error	76	(410.46)	
Intuition			
Learning condition (L)	1	0.02	.00
Familiarity condition (F)	1	0.34	.00
L × F	1	0.63	.01
Error	76	(254.89)	
Rules			
Learning condition (L)	1	0.10	.00
Familiarity condition (F)	1	3.22	.04
L × F	1	0.03	.00
Error	76	(535.98)	
Memory			
Learning condition (L)	1	1.10	.01
Familiarity condition (F)	1	0.01	.00
L × F	1	0.11	.00
Error	76	(260.77)	

Note. Values in parentheses represent mean square errors. There were no significant effects. Analyses of variance (ANOVAs) were conducted separately for each decision strategy. Descriptive statistics are reported in Table C12.

(*Appendixes continue*)

Table C12
Experiment 3: Mean Percentage of Responses for Analyses of Variance Reported in Table C11

		Decision strategy				
Condition	*N*	Random	Familiarity	Intuition	Rules	Memory
Look						
Familiarity reported	20	17 (4.7)	34 (5.6)	20 (3.7)	14 (3.2)	15 (4.4)
Familiarity unreported	20	12 (2.3)	40 (4.1)	23 (3.7)	15 (4.8)	10 (2.4)
Total	40	14 (2.6)	37 (3.5)	22 (2.6)	14 (2.9)	13 (2.5)
Rules search						
Familiarity reported	20	8 (1.7)	32 (3.7)	25 (2.9)	22 (4.6)	13 (4.3)
Familiarity unreported	20	14 (3.5)	28 (4.5)	23 (3.9)	25 (7.2)	11 (3.0)
Total	40	11 (2.0)	30 (2.9)	24 (2.4)	24 (4.2)	12 (2.6)
Total						
Familiarity reported	40	12 (2.6)	33 (3.3)	22 (2.3)	18 (2.9)	14 (3.0)
Familiarity unreported	40	13 (2.1)	34 (3.2)	23 (2.7)	20 (4.4)	10 (1.9)
Total	80	13 (1.6)	33 (2.3)	23 (1.8)	19 (2.6)	12 (1.8)

Note. Values in parentheses represent standard error of the mean.

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