Cognition 114 (2010) 372–388

Contents lists available at ScienceDirect

Cognition

journal homepage: www.elsevier.com/locate/COGNIT

Fluency does not express implicit knowledge of artificial grammars

Ryan B. Scott *, Zoltan Dienes

Department of Psychology, University of Sussex, Pevensey Building, Falmer, Brighton BN1 9QH, United Kingdom

ARTICLE INFO

Article history:
Received 31 December 2008
Revised 21 September 2009
Accepted 14 October 2009

Keywords:
Fluency
Familiarity
Implicit learning
Artificial grammar learning
Unconscious knowledge

ABSTRACT

It is commonly held that implicit knowledge expresses itself as fluency. A perceptual clarification task was used to examine the relationship between perceptual processing fluency, subjective familiarity, and grammaticality judgments in a task frequently used to produce implicit knowledge, artificial grammar learning (AGL). Four experiments examined the effects of naturally occurring differences and manipulated differences in perceptual fluency, where decisions were based on a brief exposure to test-strings (during the clarification task only) or normal exposure. When perceptual fluency was not manipulated, it was weakly related to familiarity and grammaticality judgments, but unrelated to grammatical status and hence not a source of accuracy. Counterbalanced grammatical and ungrammatical strings did not differ in perceptual fluency but differed substantially in subjective familiarity. When fluency was manipulated, faster clarifying strings were rated as more familiar and were more often endorsed as grammatical but only where exposure was brief. Results indicate that subjective familiarity derived from a source other than perceptual fluency, is the primary basis for accuracy in AGL. Perceptual fluency is found to be a *dumb heuristic* influencing responding only in the absence of actual implicit knowledge.

1. Introduction

There is substantial evidence that the knowledge acquired in implicit learning – especially of artificial grammars – is expressed largely as familiarity, defined as the subjective feeling of oldness elicited by a stimulus (e.g. Higham, 1997; Johnstone & Shanks, 2001; Kinder & Assmann, 2000; Norman, Price, Duff, & Mentzoni, 2007; Scott & Dienes, 2008; Servan Schreiber & Anderson, 1990). The question now arises as to the basis of that familiarity. In the memory literature familiarity has been proposed to result from perceptual or conceptual processing fluency (Jacoby & Dallas, 1981), or surprising fluency (Whittlesea & Williams, 2000). It has been logical to infer that perceptual fluency accounts for familiarity in artificial grammar learning (AGL) and that it is thus the means by which implicit knowledge affects classification either generally or when employing certain strategies (Kinder, Shanks, Cock, & Tunney, 2003; Whittlesea & Price, 2001). However, evidence that perceptual fluency contributes to familiarity is far from conclusive in either recognition memory generally (e.g. Kinoshita, 2002; Levy, Stark, & Squire, 2004; Stark & Squire, 2000; Wagner, Gabrieli, & Verfaellie, 1997) or in AGL in particular (e.g. Chang & Knowlton, 2004; Lieberman, Chang, Chiao, Boohheimer, & Knowlton, 2004; Newell & Bright, 2001; Zizak & Reber, 2004). The current study examines the role of perceptual fluency in AGL, evaluating its influence on subjective ratings of familiarity and grammaticality judgments, and how this influence differs when people can or cannot freely use veridical implicit knowledge.

1.1. The role of familiarity in AGL

AGL has been one of the most commonly employed paradigms for the study of implicit learning (Pothos, 2007; A.S. Reber, 1989). In a typical AGL experiment participants are exposed to letter strings conforming to a complex set of rules referred to as a grammar. The strings are commonly

* Corresponding author. Tel.: +44 781629157.
E-mail address: r.b.scott@sussex.ac.uk (R.B. Scott).

0010-0277/$ - see front matter © 2009 Elsevier B.V. All rights reserved.
doi:10.1016/j.cognition.2009.10.010

presented under the guise of a short-term memory task with participants unaware of their rule-based nature. At test, participants are informed of the existence of rules and asked to judge which of a new set of strings are grammatical. Participants are typically able to discriminate the grammatical strings with above-chance accuracy despite believing they are guessing or using intuition and despite being unable to verbalise the rules of the grammar (e.g. Allwood, Granhag, & Johansson, 2000; Channon et al., 2002; Dienes & Altmann, 1997; Dienes, Altmann, Kwan, & Goode, 1995; Dienes & Longuet Higgins, 2004; Dienes & Scott, 2005; A.S. Reber, 1967; Tunney & Altmann, 2001). A.S. Reber (1967) originally proposed that the ability to discriminate grammatical strings resulted from the implicit acquisition of regularities encountered during learning. Since that time research has proceeded to examine the nature of the regularities acquired. These are now known to include commonly recurring fragments or chunks of the training-strings (Dulany, Carlson, & Dewey, 1984; Knowlton & Squire, 1994; Perruchet & Pacteau, 1990; Servan Schreiber & Anderson, 1990), the pattern of repetitions within training-strings (Brooks & Vokey, 1991; Vokey & Higham, 2005), and knowledge of whole training exemplars (Vokey & Brooks, 1992). Similarity between training-strings and test-strings arising from any of these features could in principle result in familiarity. Servan Schreiber and Anderson were the first to characterise the knowledge acquired in this way. The resulting familiarity account holds that grammatical strings, by virtue of conforming to the grammar, are more likely to have properties seen in training and will consequently feel more familiar. Discrimination performance then results from more familiar strings being endorsed as grammatical.

There is considerable evidence supporting this account of AGL. Signal detection analyses of implicit learning tasks are consistent with decisions based on a continuous underlying dimension, such as familiarity, but not with certain rule-based accounts e.g. where a limited number of rules lead to black and white decisions (Kinder & Assmann, 2000; Lotz & Kinder, 2006). Successful computational models of AGL, and implicit learning generally, also assume a continuous output from the network that reflects similarity (for a review see Cleeremans & Dienes, 2008). More directly, Johnstone and Shanks (2001) showed that the objective similarity of training and test-strings strongly predicts grammaticality judgements. Finally, direct evidence has been provided by Scott and Dienes (2008) who showed that subjective ratings of the familiarity of test-strings were reliably predicted by structural similarity measures (mean $R = .45$), and that those familiarity ratings themselves reliably predicted grammaticality judgments (*Mean* $r = .64$).

1.2. The fluency hypothesis

Jacoby and Dallas (1981) proposed that when processing an item with relative ease, or *fluently*, people may attribute this to the item having been seen before and experience it as familiarity. This notion was developed further by Whittlesea and Williams (2000) who demonstrated that familiarity arises from a discrepancy with expected fluency. In AGL perceptual fluency could result from repetition priming during training; the elements most commonly observed in training would subsequently be processed more fluently at test. Given that grammatical test-strings have more in common with training-strings than do ungrammatical test-strings, the resulting difference could, in principle, be a source of accurate responding. Buchner (1994) found evidence supporting grammaticality as a source of differential perceptual fluency in AGL. Employing a perceptual clarification task to measure naturally occurring differences in the perceptual fluency of test-strings, Buchner found grammatical strings to be identified on average 200 ms faster than ungrammatical strings. This is an important and widely cited result. The implication for fluency as a potential source of implicit knowledge both in AGL and implicit learning generally make replication an imperative. The need to explore the generalisability of the effect is particularly acute in light of potential alternative explanations for the differences observed.

Fluency is known to be affected by a range of factors, most obviously repetition. Repetition priming has been demonstrated to enhance perceptual fluency in a range of experimental contexts (e.g. Jacoby & Dallas, 1981; Tulving, Schacter, & Stark, 1982). When parsing a string, if a letter is the same as the previous letter then within-string repetition priming will result in that letter being perceived more fluently. For grammar A of Buchner (1994), the only grammar used in Experiment 1, grammatical test-strings contained more repetitions than ungrammatical strings e.g. TXXTVV vs. TVXTVV. Based on this difference alone, grammatical strings would be expected to be perceived more fluently. However, letter repetition is only one feature known to influence fluency, others include the repetition of larger elements (e.g. bigrams) and the presence or absence of symmetry (R. Reber, Schwarz, & Winkielman, 2004). These superficial features are features that a string has intrinsically, i.e. can be determined from the string alone because they are not a relation between the string and training-strings. All such possible superficial test-string features will be controlled only when grammatical and non-grammatical strings are counterbalanced.

In addition to controlling for alternative sources of fluency, where fluency is assessed using a reaction-time task other influences on response times must also be avoided. In Buchner (1994) Experiment 1 the perceptual clarification task was not followed by any other decision. In Experiment 2, however, participants were required to make grammaticality and recognition judgements after completing the clarification task. Crucially, this was done with the test-string no longer available for reference. Under these circumstances participants might be expected to delay their response to the clarification task until arriving at a decision for the subsequent judgment. Consistent with this influence, the average identification time was 1700 ms longer and the difference between identification times for grammatical and ungrammatical strings 117 ms (66%) greater in Experiment 2 than for the same materials in Experiment 1. Where identification times reflect decision processes, theories from the categorization literature make clear predictions regarding how identification times will be affected. The *RT-Distance Hypothesis*, based on *decision* *bound theory*, holds that reaction time decreases with the distance between the perceptual effect and the decision boundary (Ashby, Boynton, & Lee, 1994). Scott and Dienes (2008) found evidence that in AGL the decision boundary lies approximately at the mean familiarity. Strings with rated familiarity greater than the mean were more likely to be categorised as grammatical while those with familiarity less than the mean were more likely to be categorised as ungrammatical. Furthermore, participants' confidence in their judgments increased with the extremity of familiarity i.e. the further a string's familiarity was from the mean. This arrangement predicts that the more extreme the familiarity – either high or low – the quicker the string will be identified. This prediction is readily distinguishable from that of the fluency hypothesis which predicts faster identification times only for higher familiarity.

A negative relationship between identification times and the extremity of familiarity ratings would indicate that identification times are being influenced by decision processes. Under such circumstances, if the extremity of familiarity ratings is greater for grammatical than ungrammatical strings then identification times would be shorter for grammatical strings independent of differences in fluency. Analysis of the data from Scott and Dienes (2008) revealed precisely this pattern; the familiarity ratings for grammatical test-strings were further from the mean test-string familiarity (were more extreme) than the ratings for ungrammatical test-strings.[1] A reliable replication of the finding that grammaticality is related to fluency therefore requires adequate control both over alternative sources of fluency and over the effect of decision processes on the reaction-time task.

Assuming perceptual fluency is related to grammaticality it would still need to influence responding, either by affecting familiarity or by some other means, in order to be a source of accuracy. A relationship between perceptual fluency and grammaticality judgments was not observed by Buchner (1994) but has been observed where fluency has been artificially manipulated. Kinder et al. (2003) employed a perceptual clarification task where the rate at which strings clarified (appearing pixel by pixel) was varied in order to artificially manipulate perceptual fluency. They found that strings clarifying more quickly had an increased chance of being classified as grammatical, and concluded that people exploit perceptual fluency to make their grammaticality judgments. Such an effect has not been universally observed however. More generally, manipulating perceptual fluency has been found to significantly influence the rated liking of test-strings but not judgments of grammaticality (Newell & Bright, 2001; Zizak & Reber, 2004). However, even a small influence of perceptual fluency on classification judgments could be of crucial importance in understanding the nature of implicit knowledge. Much of what is learnt in AGL is amenable to conscious report, what is of enduring interest however, is the presence of above-chance accuracy in the absence of verbalizable knowledge. Perceptual fluency, if derived from grammaticality, could account for that important subset of responses.

If perceptual fluency were to contribute to a subset of responses it might be apparent depending on the type of strategy adopted. Whittlesea and Price (2001) proposed that the use of perceptual fluency in decision making varies depending on whether processing is analytical or non-analytical. Kinder et al. (2003) developed a related idea in the context of AGL. They found that manipulating fluency influenced grammaticality judgments but left recognition judgments unaffected except when all test-strings were new – preventing the use of recollection. They postulate that participants exploit either a *fluency heuristic* or a *recollection heuristic* depending on the task, with the latter insensitive to fluency. When making grammaticality decisions based on a non-analytical approach, such as familiarity, people are thought to adopt processing fluency as the default strategy. In contrast when making more explicit recognition judgments they are thought to rely less on fluency and more on recollection processes. However, other research findings provide a possible alternative account for this pattern of results. Whittlesea and Leboe (2000) showed that when participants can exploit either fluency or structural similarity to make grammaticality judgments that they reliably favour the latter. Willems, van der Linden, and Bastin (2007) similarly found that in preference and recognition judgments the influence of processing fluency depended on the amount of information contained in the stimuli. And most recently, Johansson (2009) found that fluency manipulations influenced grammaticality judgments made under response deadlines but not those made under free response. Together these findings are more consistent with fluency being exploited where other sources of judgment are restricted. In Kinder et al.'s study the test-strings were presented only briefly during a perceptual clarification task, with participants required to make their grammaticality judgments based on that momentary exposure. This contrasts with the standard AGL protocol where test-strings are available for reference while participants judge their grammaticality. The effect of fluency on recognition judgments was also only observed where the usual basis for that judgment was restricted i.e. where none of the test-strings had in fact been seen before. As such, it is feasible that the observed difference in sensitivity to the fluency manipulation resulted not from the use of different heuristics but simply from the presence or absence of alternative bases for decision.

1.3. Objectives and experimental approach

The research findings relating to the role of fluency in AGL raise three crucial questions: (1) Can the relationship between grammaticality and perceptual fluency observed by Buchner (1994) be replicated where the potential effects of other sources of fluency and decision processes on identification times are eliminated? Confirming the relationship between fluency and grammaticality is essential to establishing whether fluency has the potential to contribute to accuracy and be a source of the non-verbaliz-

[1] A positive relationship between the mean and SD is not uncommon (Montgomery, 1991). This would for example result if the error in the estimate of familiarity is a constant percentage of the estimate's magnitude.

able knowledge observed in AGL. (2) To what extent does the influence of perceptual fluency in AGL differ with more or less opportunity to process the grammar strings and with the adoption of different decision strategies? Understanding the basis of knowledge in AGL requires that we establish the contribution of fluency where the usual sources of judgment are not restricted. (3) What is the relationship between the subjective experience of familiarity and perceptual fluency in AGL? Scott and Dienes (2008) demonstrated that subjective familiarity can largely account for the accuracy of responding in AGL but there has been no investigation of how subjective familiarity relates to perceptual fluency in this paradigm. The experiments in the current study were devised to address each of these questions.

Examining naturally occurring differences in perceptual fluency is the only means to confirm whether fluency is related to grammaticality but cannot establish whether a relationship between fluency and responding is due to correlation or cause. Examining the effects of manipulated fluency can establish whether a relationship is causal, but because the fluency variations are artificial they may not be representative of those occurring naturally. We therefore exploited both approaches: Experiments 1 and 2 examined naturally occurring differences in perceptual fluency, and Experiments 3 and 4 examined the effect of manipulating perceptual fluency. We explore the effect of restricting exposure to the test-strings under each approach; in Experiments 1 and 3 strings are available for reference while making grammaticality judgments while in Experiments 2 and 4 judgments must be made after only the brief presentation occurring during the clarification task. The restricted exposure in Experiments 2 and 4 also permits us to examine whether decision processes compromised the assessment of fluency under such circumstances; this would reveal itself as shorter identification times for more extreme familiarity ratings.

The effect that superficial test-string features, such as letter repetition, had on fluency estimates was counterbalanced across grammaticality in all experiments. This was achieved by employing the two grammar design of Dienes and Altmann (1997). This involves training half the participants on one grammar, and half on another, and having all participants classify the same set of test-strings exactly half of which conform to each. In this way the ungrammatical test-strings for half the participants are grammatical for the other half and analysis collapsed across grammar ensures counterbalancing. This approach has the additional benefit that while the effects are counterbalanced we can still examine whether they have the capacity to influence fluency estimates.

In addition to grammaticality judgments participants were required to rate the familiarity of each test-string and to report the decision strategy used for each judgment. The reporting of familiarity ratings permitted the relationship between fluency and subjective familiarity to be examined. The reporting of decision strategy permitted the influence of fluency on grammaticality judgments to be contrasted according to the type of strategy employed. Previous research has demonstrated that the nature of participants' responses is quantifiably different depending on the strategy they report using (Dienes & Scott, 2005; Scott & Dienes, 2008).

In sum, Experiment 1 examined the relationship between fluency, grammaticality, and familiarity where superficial sources of fluency were counterbalanced and the influence of decision processes were avoided by having strings available for reference when grammaticality judgments were made. Experiment 2 had participants make their grammaticality judgments having only seen the test-strings during the clarification task. This was done to test the prediction that under those circumstances decision processes would influence responses times, resulting in shorter identification times for more extreme familiarity and hence for grammatical strings. Experiments 3 examined whether the influence of manipulating perceptual fluency on grammaticality judgments observed by Kinder et al. (2003) would be eliminated if participants were able to reference the test-strings when making their grammaticality judgments. Experiment 4 aimed to replicate Kinder et al.'s original result by limiting test-string exposure to that obtained during the clarification task. Experiments 3 and 4 also provided the opportunity to replicate key findings from Experiments 1 and 2 respectively.

2. Experiment 1

This experiment sought to replicate Buchner's (1994) finding, that grammaticality is related to perceptual fluency, while counterbalancing superficial test-string features and avoiding the potential influence of decision processes on identification times. It was predicted that, controlling for these influences, the relationship would be reduced or eliminated. We further evaluated the extent to which naturally occurring differences in perceptual fluency predicted familiarity and grammaticality judgments and how this varied with the decision strategy adopted. Familiarity and grammaticality judgments were made under standard conditions, namely with test-strings available for reference when making those judgments. This was done to ensure that all usual sources of knowledge were available to participants when making their decisions, and to eliminate any temptation to delay responding in the perceptual clarification task as a means to facilitate the subsequent judgments.

2.1. Method

2.1.1. Participants

Forty participants were recruited from The University of Sussex library (10 males and 30 females). Participants ranged in age from 18 to 38 years with a mean age of 22 ($SD = 3.9$). All participants were University of Sussex students and naive to the experimental hypothesis. Participants were randomly assigned to one of two experimental conditions; 20 were trained on grammar A and 20 were trained on grammar B.

2.1.2. Materials

Two finite state grammars were used to generate the letter strings. Both grammars were taken from (A.S. Reber,

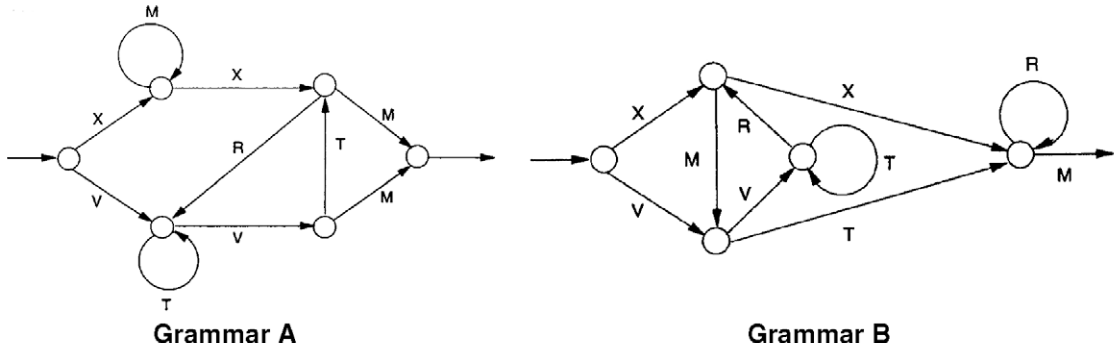

Fig. 1. The two finite state grammars used to generate the strings; taken from (A.S. Reber, 1969).

1969) and are shown in Fig. 1. Both grammars use the same letter set (M, T, V, R and X) and contain the same set of valid starting bigrams and final letters. The training sets comprised 16 strings (from the appropriate grammar) repeated three times in random orders. The test set comprised a combination of 16 strings from each grammar that had not been seen during training, presented twice in random order. The selection of strings was made such that there was the same number of strings of each length in both training sets and that the proportion of strings of each length was the same for training and test sets. The grammar strings used are listed in Appendix A. Strings were presented in black on a white background at the centre of a 12-in computer screen. The viewing distance was approximately 55 cm and the letter size selected to achieve an average visual angle for the string widths of 2.8°. This visual angle was chosen to match the average for strings of the same length in Buchner (1994).

2.1.3. Procedure

2.1.3.1. Training stage. The training-strings were displayed one at a time for 5 s each followed by a blank screen for a further 5 s. Participants were required to memorise each string while it was on the screen and then to write down as much of that string as they could remember while the screen was blank. They were supervised and not permitted to write while the strings were on the screen. The presentation order was separately randomised for each participant.

2.1.3.2. Test stage. Participants were informed that the order of letters in the training-strings had obeyed a complex set of rules, that they were about to see a completely new set of strings, and that exactly half of the new strings would obey the same rules. For each trial the test-string was initially presented as part of a timed perceptual clarification task. This was followed by a matching task where participants indicated which of two strings they believed they had seen. Finally, the original string was re-presented in the clear for participants to rate its familiarity, judge its grammaticality, and to indicate what they believed to be the basis for their grammaticality judgment. The order in which familiarity and grammaticality judgments were requested was randomised for the first presentation of each string and counterbalanced across string presentations. The presentation order for the test-strings was separately randomised for each participant but kept the same for pass 1 and pass 2. This was done to keep the delay between presentations the same for each string and hence balance priming effects.

For the clarification task participants were advised that the string would appear gradually and that they were to press the space bar the moment that they were able to make out all the letters. They were told that the speed of their response was crucial to the experiment. A black cross provided a 2 s warning that clarification was about to start. Replicating Buchner's (1994) procedure, the letter strings were obscured by a black rectangle 0.3° larger than the letter string on each edge. Pixels were then removed continuously from random locations within the masking rectangle until the space bar was pressed. Pixels were removed at a rate of 0.1% of the total number of mask pixels per screen refresh (every 16.67 ms). When the space bar was pressed the screen was cleared and, contingent on the identification time being within suitable bounds, the matching task began. Anticipatory (<0.5 s) or delayed responses (>20 s) resulted in a warning message being displayed after which the trial was aborted and repeated at a later stage of the experiment. For the matching task a string not used in training or test was selected to match the length and grammar of the test-string i.e. if the test-string was grammatical so was the foil and vice versa. The test-string and match string were presented one above the other with their position assigned randomly. Participants were required to identify, by numbered position, the string they believed they had seen in the clarification task.[2] After the matching task the target string was re-presented for participants to judge its grammaticality and familiarity. For the familiarity judgment participants were asked to rate how familiar the string felt to them on a scale of 0–100; where 0 indicated that it was not at all familiar and 100 that it was completely familiar. For the grammaticality judgments participants were asked to indicate whether they believed the string obeyed the rules from the training stage (yes or no). Participants were encouraged to rely on their gut feelings when completing this task.

[2] This matching task differed subtly from that employed in Buchner (1994). In that previous study participants were shown just one string and asked whether or not it was the one seen during clarification.

Immediately following the grammaticality judgment participants were asked to indicate the basis on which they believed they had made that decision: completely random, intuition, familiarity, rules, or memory. These *decision strategies* were defined as follows: Completely Random – you had no idea so you literally chose yes or no at random; Intuition – you had some confidence but could not say on what you based your answer; Familiarity – you chose yes or no based on how familiar or unfamiliar the string felt; Rules – you based your answer on one or more rules or partial rules that you derived and you could state the nature of the rules if required; Memory – if you answered 'Yes' it was because you specifically recalled seeing part or all of that string in stage 1. If you answered 'No' it was because you are certain that you did not see any strings resembling the current one in training.

2.1.4. Design

The two grammar design, described in the introduction, ensured that all superficial test-string features were counterbalanced across grammaticality. The main dependent variables were (1) identification time in the perceptual clarification task, (2) accuracy in the matching task, (3) grammaticality judgment, and (4) subjective familiarity rating. The key independent variables were all within subject and included (a) grammaticality (with two levels: grammatical vs. ungrammatical), (b) presentation (with two levels: first presentation vs. second presentation), and (c) decision strategy (with five levels: random selection vs. intuition, vs. familiarity vs. rules vs. memory).

2.2. Results

The following statistical procedures were adopted for all experiments. An alpha level of .05 was used for all statistical tests and all reported *p*-values are for two-tailed significance unless otherwise stated. Identification times greater than three standard deviations from the mean for each participant were considered outliers and excluded from the analyses. The individual regression equation method recommended by Lorch and Myers (1990) was adhered to for all multiple regression analyses.

2.2.1. Learning and unconscious knowledge

The mean percentage of grammaticality judgments correct was 69 ($SE = 1.6$), significantly greater than chance (50%), $t(39) = 12.15$, $p < .001$, $d = 1.92$, indicating that learning took place. Accuracy was also above chance examining only those judgments attributed to random selection ($M = 61$, $SE = 6.3$), $t(23) = 1.78$, $p = .044$ (one-tailed), $d = .36$, indicating the presence of unconscious knowledge as measured by the guessing criterion.[3] See Dienes (2004, 2008) for the assumptions of this and other subjective measures.

2.2.2. Validating identification times as a measure of processing fluency

Identification times for the clarification task were consistently within bounds, including just one delayed response (>20 s) and no anticipatory responses (<0.5 s). Just five out of the 2560 responses were excluded as outliers. The mean percentage of correct judgments in the matching task following the perceptual clarification procedure was 93 ($SE = .7$). This figure did not differ for grammatical ($M = 93$, $SE = .9$) and ungrammatical strings ($M = 93$, $SE = .7$), $t(39) = .32$, $p = .753$, $d_z = .05$. The high level of accuracy and the consistency across grammaticality indicates that participants were performing the clarification task as intended i.e. waiting until they could read the strings before pressing the space bar.

With the grammar strings available for reference when participants made their grammaticality judgments it was predicted that decision processes would not influence identification times in the perceptual clarification task. Were identification times to reflect decision processes the RT-Distance Hypothesis predicts shorter identification times for more extreme familiarity ratings (high or low) i.e. a negative relationship between RT and the extremity of familiarity. The extremity of familiarity was calculated as the absolute value of the standardized familiarity rating for each participant (the absolute z-familiarity). The mean correlation between absolute z-familiarity and identification time was positive (*Mean* $r = .02$, $SE = .02$) and non-significant, $t(39) = 1.06$, $p = .295$, $d = .15$, $CI_{.95} = -.02, +.07$, consistent with identification times not being influenced by decision processes. This result is replicated in Experiment 3 where test-strings were again available for reference when making grammaticality judgments, but is found to be markedly different in Experiments 2 and 4 where grammaticality judgments were based solely on exposure during the clarification task.

Superficial test-string features were hypothesised to have contributed to the difference in perceptual identification times between grammatical and ungrammatical strings observed by Buchner (1994). Our design ensures that all such features are counterbalanced across grammaticality but still permits their influence on identification times to be examined. We examine the influence of *letter changes* on identification times as an illustrative example. Letter changes is the converse of letter repetitions e.g. XXX has no letter changes while XTV has 2. Fewer letter changes means more repetitions and hence the more within-string repetition priming should enhance fluency. Presentation (1st vs. 2nd time the test-string was rated) and string length would also be expected to influence identification times and hence we control for these factors in our analysis. Identification time was simultaneously regressed on presentation, string length (in letters), and letter changes. The mean standardized coefficients for each of these predictors were significant: Presentation (*Mean* $\beta = -.19$, $SE = .04$), $t(39) = 4.50$, $p < .001$, $d = .70$; Length (*Mean* $\beta = .13$, $SE = .03$), $t(39) = 5.01$, $p < .001$, $d = .81$; Letter changes (*Mean* $\beta = .05$, $SE = .02$), $t(39) = 1.85$, $p = .036$ (one-tailed), $d = .31$. Consistent with predictions, the fewer letter changes a string contained the faster it was identified i.e. the more fluently it was perceived. This effect was also

[3] The percentage of correct responses attributed to random selection was numerically greater than chance in all the experiments and significantly so in all except Experiment 2. Collapsing across experiments the mean percentage correct was 59 ($SE = 2.6$) and significantly above chance, $t(119) = 3.25$, $p = .002$, $d = .31$.

significant in each of the other three experiments (all $p < .05$ two-tailed). In Buchner's study grammatical strings contained fewer letter changes than ungrammatical strings (Exp1: grammatical = 3.55, ungrammatical = 4.10), as such identification times for grammatical strings would be expected to be shorter irrespective of whether fluency was related to grammaticality.

2.2.3. Perceptual fluency and grammaticality

Consistent with predictions, the mean perceptual identification time for ungrammatical minus grammatical strings ($M = 55$ ms, $SE = 44$ ms) was significantly less than observed in both Buchner's (1994) Experiment 1 ($M = 177$ ms, $SE = 51$ ms), $t(110) = 1.81$, $p = .037$ (one-tailed), $d = .34$, and Experiment 2 ($M = 227$ ms, $SE = 72$ ms), $t(99) = 2.10$, $p = .044$, $d = .39$. The difference between ungrammatical ($M = 8278$ ms, $SE = 264$ ms) and grammatical ($M = 8224$ ms, $SE = 256$ ms) strings was non-significant, $t(39) = 1.25$, $p = .219$, $d_z = .19$, $CI_{.95}$ of diff. = −34, +143, with a power of .80 of detecting an effect size equivalent to that observed by Buchner.[4] As predicted, counterbalancing superficial test-string features and avoiding the influence of decision processes on identification times, the difference in perceptual fluency for grammatical and ungrammatical strings was significantly less than observed without those controls, and was no longer reliably different from zero.

2.2.4. Perceptual fluency and familiarity

The mean correlation between identification time and subjective familiarity was small but significant (*Mean* $r = -.08$, $SE = .03$), $t(39) = 2.88$, $p = .006$, $d = .47$, indicating a weak ($r < .10$) positive relationship between perceptual fluency and familiarity.[5] The mean correlation between grammaticality and familiarity was substantial (*Mean* $r = .41$, $SE = .03$), $t(39) = 13.52$, $p < .001$, $d = 2.15$. When familiarity was simultaneously regressed on both predictors the mean standardized coefficient was significant for both grammaticality (*Mean* $\beta = .40$, $SE = .03$), $t(39) = 13.29$, $p < .001$, $d = 2.11$, and identification time (*Mean* $\beta = -.08$, $SE = .03$), $t(39) = 3.07$, $p = .004$, $d = .50$, indicating that both variables made an independent contribution to familiarity. These results suggest that aspects of the stimuli unrelated to perceptual fluency, but which were related to grammaticality, made a large contribution to subjective familiarity.

2.2.5. Perceptual fluency and grammaticality judgment

The mean correlation between identification time and grammaticality judgment was small but significant (*Mean* $r = -.06$, $SE = .02$), $t(39) = 2.63$, $p = .012$, $d = .40$, indicating a weak ($r < .10$) positive relationship between perceptual fluency and whether a string was endorsed as grammatical. As shown above, identification times were also related to familiarity (*Mean* $r = -.08$). When grammaticality judgment was simultaneously regressed on both identification time and familiarity, the mean standardized coefficient for familiarity was significant (*Mean* $\beta = .73$, $SE = .02$), $t(39) = 35.85$, $p < .001$, $d = 5.62$, while that for identification time did not reach significance (*Mean* $\beta = -.01$, $SE = .01$), $t(39) = .61$, $p = .549$, $d = .10$. Together these results show that fluency had a small but significant influence on grammaticality judgments and, following the Baron and Kenny (1986) mediation procedure, are indicative of its contribution being mediated by familiarity.

Analyses were conducted to test predictions consistent with Kinder et al. (2003) – that perceptual fluency has less influence where a recollective strategy is used. Responses attributed to recollective memory were contrasted with those attributed to familiarity. The difference in identification time for strings judged to be ungrammatical minus strings judged to be grammatical (the fluency difference) was non-significantly *less* for responses attributed to familiarity ($M = -72$ ms, $SE = 198$ ms) vs. recollective memory ($M = 288$ ms, $SE = 186$ ms), $t(27) = 1.24$, $p = .112$, $d_z = -.15$, $CI_{.95}$ of diff. = −953, +234. This is the opposite pattern to that predicted by Kinder et al., however the confidence intervals do not reliably exclude effects consistent with their theory. Comparisons between decision strategies in the subsequent experiments were similarly null but limited by the available power and are consequently not reported.

2.2.6. The conscious and unconscious influence of familiarity

Replicating Scott and Dienes (2008), familiarity ratings were reliably predicted by objective measures of the structural similarity between training and test-strings, including associative chunk strength and repetition structure (*Mean adjusted* $R^2 = .27$, $SE = .02$), $t(39) = 11.42$, $p < .001$, $d = 1.8$.[6] Consistent with the strong correlation between familiarity and grammaticality judgment, participants reported using familiarity to make the largest proportion of their grammaticality judgments ($M = 33\%$, $SE = 2.7\%$). However, also replicating the earlier study, controlling for grammaticality, familiarity continued to predict grammaticality judgment even when participants reported selecting their responses at random. When grammaticality judgment was simultaneously regressed on familiarity and grammaticality for responses attributed to random selection the mean standardized coefficient for familiarity was significant (*Mean* $\beta = .35$, $SE = .14$), $t(11) = 2.56$, $p = .027$, $d = .73$, while that for grammaticality did not reach significance (*Mean* $\beta = .29$, $SE = .15$), $t(11) = 2.01$, $p = .069$, $d = .58$. This suggests that, while familiarity is often consciously exploited by partici-

[4] A one-tailed power estimate was calculated based on the mean effect size of Buchner's (1994) experiments ($d_z = .40$). Note, the result is also replicated in Experiment 3 (the only other experiment providing fluency

[5] The weak relationship between familiarity and fluency does not in itself tell us that they derive from separate underlying sources. It remains technically feasible that they derive from the same source but with independent errors (e.g. Berry, Shanks, & Henson, 2008) though (cf. Runger, Nagy, & Frensch, 2009).

[6] A multiple regression predicting familiarity was conducted with the following independent variables: (1) string length in letters, (2) associative chunk strength, (3) positional associative chunk strength, (4) novel chunk proportion, (5) same letter proportion, (6) adjacent repetition proportion, and (7) global repetition proportion. These measures were related to grammaticality to varying degrees, for details and full definitions see Scott and Dienes (2008). While it would not be possible to control all these measures simultaneously, future research might usefully examine subjective feelings of familiarity while using a tool such as StimSelect (Bailey & Pothos, 2008) to control individual features.

pants, at other times it exerts an influence on judgments without their awareness.[7]

2.3. Discussion

With superficial test-string features counterbalanced across grammaticality and the potential influence of decision processes avoided, the relationship between perceptual fluency and grammaticality previously observed by Buchner (1994) was not replicated. It was further demonstrated that the imbalance of superficial test-string features in that study, letter repetitions in particular, would have contributed to the observed difference in identification times. Whether the influence of decision processes may also have contributed to the observed difference is examined in Experiment 2.

In the absence of a relationship between perceptual fluency and grammaticality, perceptual fluency cannot account for the accuracy of participants' judgments (69% correct in the present experiment). Nonetheless, there was evidence that perceptual fluency influenced responding. Consistent with a relationship between fluency and familiarity, as previously evaluated by memory reports (e.g. Jacoby & Whitehouse, 1989), perceptual fluency was found to weakly predict the familiarity of test-strings (*Mean* $r = .08$). Perceptual fluency also exerted a weak influence on grammaticality judgments (*Mean* $r = .06$), with analyses indicating that this influence was mediated by feelings of familiarity. No reliable conclusions could be drawn regarding whether the influence of perceptual fluency differed depending on the decision strategy participants adopted. These results challenge the notion that perceptual fluency is a source of implicit knowledge in AGL. Perceptual fluency in this context appears to be a *dumb heuristic* (Higham, unpublished manuscript) that does not capture knowledge of the grammar and hence contributes only noise to participants' decisions. Nonetheless, that blind influence could feasibly be greater when other sources of information are limited; this possibility is assessed by Experiments 3 and 4.

In addition to examining the role of fluency, Experiment 1 replicated key familiarity-related findings from Scott and Dienes (2008). Familiarity ratings were strongly predicted by the collection of measures assessing the objective similarity of training-strings and test-strings (*Mean* $R^2 = .27$). Familiarity ratings in turn strongly predicted grammaticality judgments (*Mean* $r = .73$), and were reported as the basis of those judgments for the largest proportion (33%) of participant's responses. This indicates that participants were often conscious of exploiting familiarity to make their decisions. However, familiarity also significantly predicted participants' judgments even when they reported selecting their responses at random; this suggests that familiarity may exert an unconscious influence in some instances.

[7] All of the familiarity-related findings were replicated in each of the subsequent experiments. However, as they are a replication of findings presented in Scott and Dienes (2008), they are reported only in Experiment 1.

3. Experiment 2

The current experiment sought to establish whether an influence of decision processes on identification times may have contributed to the apparent relationship between fluency and grammaticality observed in Buchner's (1994) Experiment 2. Replicating that experiment, grammaticality judgments are made based solely on the test-string exposure received during the clarification task. We then examine if the resulting identification times reflect decision processes and whether this results in shorter identification times for grammatical strings.

3.1. Method

3.1.1. Participants

Forty participants were recruited from The University of Sussex library (12 males and 28 females). Participants ranged in age from 18 to 32 years with a mean age of 21 ($SD = 2.5$). All participants were University of Sussex students and naive to the experimental hypothesis. Participants were randomly assigned to one of two experimental conditions; 20 were trained on grammar A and 20 were trained on grammar B.

3.1.2. Materials

All materials were identical to those used in Experiment 1.

3.1.3. Procedure

The procedure was the same as Experiment 1 with the exception that at test, the matching task was omitted and the test-strings removed after the perceptual clarification task. These two changes ensured that familiarity and grammaticality judgments were based solely on the brief exposure received while the strings clarified. Instructions for the clarification task remained the same with participants told to press the space bar the moment that they were able to make out all the letters.

3.1.4. Design

The design was the same as Experiment 1 with the exception that, with the matching task removed, the dependent variables included only (1) identification times in the clarification task, (2) grammaticality judgments, and (3) subjective familiarity ratings.

3.2. Results

3.2.1. Learning and Unconscious Knowledge

The mean percentage of grammaticality judgments correct was 69 ($SE = 1.5$), significantly greater than chance (50%), $t(39) = 12.60$, $p < .001$, $d = 1.99$, and the same as that achieved in Experiment 1 ($M = 69$, $SE = 1.6$). The accuracy of grammaticality judgments attributed to random selection, while numerically above that predicted by chance ($M = 53$, $SE = 6.1$), did not achieve significance, $t(23) = .54$, $p = .590$, $d = .10$.

Table 1
Experiment 2: mean identification times in milliseconds by familiarity ratings banded into quintiles.

Familiarity quintile	N	Mean	SE
1st (Low)	38	9788	334
2nd	38	9946	330
3rd (Medium)	40	10,049	305
4th	39	9504	294
5th (High)	39	9347	275

3.2.2. The effect of decision processes on identification times

Identification times for the clarification task were largely within bounds, including just five delayed responses (>20 s) and one anticipatory response (<0.5 s). Six identification times were excluded as outliers. Identification times were compared with those from Experiment 1. In that experiment strings remained present for the grammaticality judgments made after the clarification task. In Experiment 2 strings were removed after clarification and hence unavailable for reference when judging grammaticality. Consistent with participants delaying responding in the clarification task until they had made a decision regarding the subsequent grammaticality judgment, identification times in Experiment 2 (M = 9747 ms, SE = 296 ms) were significantly longer than those for Experiment 1 (M = 8245 ms, SE = 258 ms), $t(78) = 3.82$, $p < .001$, $d = .94$. The difference of 1502 ms was comparable to that observed between the common stimuli (i.e. grammar A) of Buchner's Experiments 1 and 2 (1711 ms).

To further test whether this increase in identification time reflected decision processes, the relationship between identification time and the extremity of familiarity (absolute z-familiarity) was examined. In contrast to Experiment 1 but as predicted by the RT-Distance Hypothesis, there was a significant negative correlation between identification time and absolute z-familiarity (*Mean* $r = -.13$, $SE = .02$), $t(39) = 6.55$, $p < .001$, $d = 1.04$.[8] The correlation was also significantly different from that observed in Experiment 1 (*Mean* $r = .02$, $SE = .02$), $t(78) = 5.30$, $p < .001$, $d = 1.15$. Table 1 shows mean identification times by familiarity ratings, where participants' ratings are banded into five equal percentile categories (quintiles). This reveals the predicted pattern of shorter identification times for *both* lower *and* higher familiarity ratings. Identification times for the lowest quintile (M = 9785 ms, SE = 334 ms) were significantly shorter than those for the middle quintile (M = 9988 ms, SE = 317 ms), $t(37) = 2.52$, $p = .016$, $d_z = .42$ (note this directly contradicts the fluency account which predicts that less familiar strings, by virtue of having lower perceptual fluency, will be identified more slowly). Similarly, identification times for the highest quintile (M = 9347 ms, SE = 275 ms) were also shorter than those for the middle quintile (M = 10,002 ms, SE = 311 ms), $t(38) = 5.40$, $p < .001$, $d_z = .84$. These results are consistent with easier judgments, as facilitated by larger differences from the mean familiarity, being made more quickly. Together with the increase in mean identification time the results suggest that participants delayed responding during the clarification task until they had judged the strings' grammaticality.

Note, listwise means are reported in the table. These differ slightly from the pairwise means necessarily used for the *t*-test comparisons of the individual quintiles reported in the text.

The mean absolute z-familiarity for grammatical strings ($M = .88$, $SE = .02$) was also significantly greater than that for ungrammatical strings ($M = .77$, $SE = .02$), $t(39) = 5.28$, $p < .001$, $d_z = .83$. As such, with decision times shorter for strings with more extreme familiarity ratings, and with more extreme familiarity ratings assigned to grammatical strings, decision processes will have resulted in shorter identification times for grammatical strings. Consistent with this effect, and in contrast to Experiment 1, the identification times for grammatical strings (M = 9620 ms, SE = 290 ms) were significantly shorter than for ungrammatical strings (M = 9875 ms, SE = 307 ms), $t(39) = 3.51$, $p = .001$, $d_z = .56$. This difference in identification times (M = 255 ms, SE = 73 ms) was also significantly greater than that observed in Experiment 1 (M = 55 ms, SE = 44 ms), $t(78) = 2.36$, $p = .021$, $d = .53$. Our results are consistent with the differences observed between experiments in Buchner (1994) and – in addition to differences in superficial test-string features – provide another basis for the apparent relationship between perceptual fluency and grammaticality observed in that study.

With identification times affected by decision processes they do not provide a valid measure of perceptual fluency and analyses relating to identification time are therefore not conducted.

3.3. Discussion

Experiment 2 sought to replicate the apparent influence of decision processes observed in Buchner (1994) and to evaluate whether such an effect could result in a spurious relationship between perceptual fluency and grammaticality. Restricting reference to the test-strings to that received during the clarification task, as in that study, resulted in an influence of decision processes on identification times. This influence was apparent both from an overall increase in identification times (1502 ms) and a negative relationship between identification time and the extremity of familiarity. The latter is consistent with judgments of grammaticality being easier and quicker the more extreme a string's familiarity; high or low. It was further shown that grammatical strings elicited more extreme familiarity ratings. Consequently, decision processes will have caused grammatical strings to have shorter identification times. Together with the influence of superficial test-string features on fluency, these findings may account for the apparent relationship between perceptual fluency and grammaticality observed in Buchner (1994). The combination also accounts for the failure to replicate Buchner's results in Experiment 1 of the present study where both these influences were avoided.

[8] The negative correlation is also significant when grammatical and ungrammatical strings are examined separately (Ungrammatical, *Mean* $r = -.10$, $t(39) = -4.28$, $p < .001$; Grammatical, *Mean* $r = -.14$, $t(39) = -4.27$, $p < .001$).

4. Experiment 3

Experiment 3 sought to establish the extent to which artificially enhancing perceptual fluency increases the subjective familiarity of test-strings and their likelihood of being endorsed as grammatical. Kinder et al. (2003) observed a substantial effect on grammaticality judgments; however, reference to the test-strings in that study was restricted to brief exposure during the clarification task. Here we examine whether that effect occurs when the test-strings remain available for reference while making the judgments. Perceptual fluency was manipulated according the same procedure adopted by Kinder et al. (2003), namely by a variation in the rate at which strings were revealed during the perceptual clarification task. In principle, the effects of perceptual fluency arise from the rate at which stimuli are initially processed, hence revealing them at a faster rate results in the perception of greater fluency. Importantly, it also follows that the continued presence of the test-strings past the point at which they have been identified should not influence their perceived perceptual fluency. In contrast, their continued presence may permit additional processing that is unrelated to fluency and thus facilitate alternative bases for judgment. Thus the experiment tests the extent to which perceptual fluency influences responding when other sources of judgment are unconstrained.

4.1. Method

4.1.1. Participants

Forty-one participants were recruited from The University of Sussex library (15 males and 26 females). Participants ranged in age from 18 to 29 years with a mean age of 22 ($SD = 2.7$). All participants were University of Sussex students and naive to the experimental hypothesis. Participants were randomly assigned to one of two experimental conditions; 21 were trained on grammar A and 20 were trained on grammar B.

4.1.2. Materials

All materials were identical to those used in Experiments 1 and 2.

4.1.3. Procedure

The procedure was the same as that for Experiment 1 with the exception of the following modifications relating to the fluency manipulation in the test stage. Two different clarification rates were used; a slow rate which was the same as that used in Experiments 1 and 2, namely 0.1% of the total number of mask pixels at each screen refresh, and a fast rate which was double the slow rate. In the first pass through the test-strings a randomly selected half of the strings, balanced across both grammar and length, clarified at the slow rate, and the remainder at the fast rate. The assignment of clarification rates was then counterbalanced across presentations such that each string clarified once at each rate.

The effect of the fluency manipulation could be expected to diminish over time. As such, it was important to have participants make familiarity and grammaticality judgments without delay. The matching task was therefore omitted; when participants pressed the space bar in the clarification task the test-string fully clarified and remained on the screen for the grammaticality judgment. Instructions for the clarification task were unchanged.

Finally, after the test phase, participants were interviewed to establish whether they were aware of the manipulation. This included asking the following question, "*Was there anything in the test phase that you felt was strange or was being manipulated?*" Participants were categorised as showing *unprompted awareness* of the manipulation if they mentioned differences in the rate at which the strings appeared in response to this question.

4.1.4. Design

The design was the same as Experiment 1 with the exception of the following changes. With the matching task removed, the dependent variables included only (1) identification times in the clarification task, (2) grammaticality judgments, and (3) subjective familiarity ratings. One additional independent variable was included: clarification rate (fast vs. slow). The other independent variables remained the same.

4.2. Results

4.2.1. Learning and unconscious knowledge

The mean percentage of grammaticality judgments correct was 71 ($SE = 1.6$), significantly greater than chance (50%), $t(40) = 13.69$, $p < .001$, $d = 2.14$, and comparable to both Experiments 1 and 2. The percentage of grammaticality judgments correct for fast clarifying strings ($M = 72$, $SE = 1.7$) was not significantly different from that for slow clarifying strings ($M = 71$, $SE = 1.7$), $t(40) = .36$, $p = .722$, $d_z = 0.06$, $CI_{.95} = -2, +4$, indicating that accuracy was not significantly influenced by the manipulation. Consistent with Experiment 1, accuracy was also above chance for responses attributed to random selection ($M = 61$, $SE = 5.1$), $t(29) = 2.26$, $p = .032$, $d = .41$, indicating the presence of unconscious knowledge as measured by the guessing criterion.

4.2.2. Validating the fluency manipulation

Only two participants showed unprompted awareness of the different clarification rates. The average identification time for fast clarifying strings ($M = 5032$ ms, $SE = 168$ ms) was significantly shorter than that for slow clarifying strings ($M = 8216$ ms, $SE = 264$ ms), $t(40) = 26.42$, $p < .001$, $d_z = 4.13$. The difference in identification times ($M = 3184$ ms) was almost identical to that observed in Kinder et al.'s (2003) study ($M = 3183$ ms), and some 15 times the naturally occurring difference between strings classified as grammatical vs. ungrammatical observed in our Experiment 1 (204 ms).[9] The fluency manipulation is

[9] Kinder et al.'s (2003) test-strings also included old grammatical strings – those seen during training. To enable a direct comparison with the experiments reported here, only identification times for the new strings were used when calculating the difference in identification times for the two clarification rates. The difference reported is the average identification time difference from Experiments 2, 3, and 5 which were the experiments where both grammatical and ungrammatical new strings were included at test. Identification time data was provided by email (Kinder, personal communication, March 19, 2007).

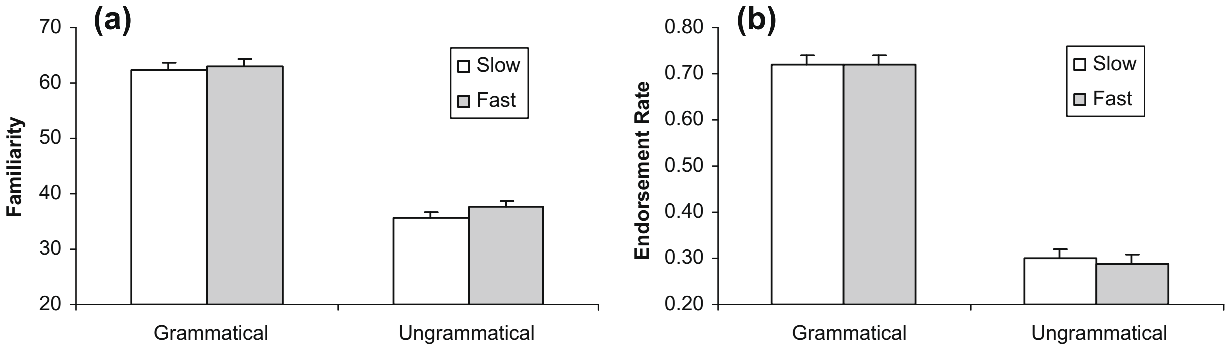

Fig. 2. Mean familiarity ratings (a) and endorsement rates (b) for grammatical and ungrammatical strings clarifying at fast and slow rates, where test-strings remained present for classification (Experiment 3). Error bars are standard errors of the difference between fast and slow rates.

therefore both comparable to the previous study and of a sufficient size that it would be expected to induce an effect.

4.2.3. Validating identification times as a measure of processing fluency

The mean identification time for slow clarifying strings (M = 8216 ms, SE = 264 ms) was not significantly different from the mean identification time from Experiment 1 (M = 8245 ms, SE = 258 ms) where all strings clarified at the slow rate, $t(79) = .08$, $p = .938$, $d = .02$. This suggests that participants performed the clarification task in the same manner as Experiment 1 despite the absence of the matching task. Furthermore, there was also no significant correlation between the extremity of familiarity (absolute z-familiarity) and identification times (*Mean* $r = .01$, $SE = .02$), $t(40) = .45$, $p = .658$, $d = .07$, $CI_{.95} = -03, +05$. Together these results indicate that, consistent with Experiment 1, where the strings are present for the grammaticality and familiarity judgments the identification times captured by the perceptual clarification task are uninfluenced by decision processes.

4.2.4. Perceptual fluency and grammaticality

If grammatical strings were perceived more fluently, and hence identified more quickly, then this should be apparent regardless of the rate at which strings clarified. All grammatical and ungrammatical strings clarified once at each rate. Results did not differ examining each rate separately and are therefore presented collapsing across rates.[10] Replicating Experiment 1, with superficial test-string features counterbalanced and the influence of decision processes on identification times avoided, the difference between ungrammatical (M = 6631 ms, SE = 210 ms) and grammatical (M = 6612 ms, SE = 218 ms) strings (*Mdiff.* = 19 ms, SE = 37 ms) was non-significant, $t(40) = .51$, $p = 615$, $d_z = .08$, $CI_{.95} = -55, +94$. There was a power of .81 of detecting an effect size equivalent to that observed by Buchner (1994). Combining the data from Experiments 1 and 3 (the only experiments providing fluency measurements unbiased by decision processes) permits an analysis with a power of .97. This again reveals no significant difference in the mean perceptual identification times of ungrammatical (M = 7444 ms, SE = 191 ms) and grammatical (M = 7408 ms, SE = 189 ms) strings, $t(80) = 1.29$, $p = .199$, $CI_{.95} = -21, +93$, $d_z = .14$.

4.2.5. The effect of clarification rate on familiarity

A 2 × 2 within subjects ANOVA on familiarity ratings with clarification rate (fast vs. slow) and grammaticality (grammatical vs. ungrammatical) as independent variables revealed a large significant main effect of grammaticality, $F(1,40) = 107.40$, $p < .001$, $\eta_p^2 = .73$, but no main effect of rate, $F(1,40) = 2.49$, $p = .123$, $\eta_p^2 = .06$, $CI_{.95} = -0.3, +2.8$, nor an interaction between them, $F(1,40) = .84$, $p = .364$, $\eta_p^2 = .02$, see Fig. 2a. This indicates that participants' feelings of familiarity were predicted by features of the strings related to grammaticality and not by manipulated differences in perceptual fluency.

4.2.6. The effect of clarification rate on grammaticality judgments

A 2 × 2 within subjects ANOVA on endorsement rate with clarification rate (fast vs. slow) and grammaticality (grammatical vs. ungrammatical) as independent variables revealed a large significant main effect of grammaticality, $F(1,40) = 187.32$, $p < .001$, $\eta_p^2 = .82$, but no main effect of rate, $F(1,40) = .16$, $p = .696$, $\eta_p^2 = .004$, $CI_{.95} = -.03, +.02$, nor an interaction between them, $F(1,40) = .13$, $p = .722$, $\eta_p^2 = .003$, see Fig. 2b. The analysis had a power of .90 to detect an effect of the fluency manipulation equivalent to that observed in Kinder et al. (2003). The results suggest that where strings remain available for reference, judgments are predicted by grammaticality but not by manipulated differences in perceptual fluency.

4.3. Discussion

Experiment 3 found that, with test-strings available for reference when making grammaticality judgments, manipulating perceptual fluency affected neither the perceived familiarity of the grammar strings nor their likelihood of being endorsed as grammatical. This finding suggests that the influence of fluency observed by Kinder et al. (2003)

[10] The difference in identification times between grammatical and ungrammatical strings was not significantly different for fast ($M = -14$ ms, SE = .05 ms) versus slow clarification rates ($M = -11$ ms, SE = .06 ms), $t(40) = .04$, $p = .969$, $d_z = .01$, $CI_{.95} = -173, +166$.

may depend on restricting alternative sources of judgement; this possibility is further examined in Experiment 4.

Replicating Experiment 1, with the grammar strings available for reference in the subsequent judgments, decision processes were not found to influence identification times in the clarification task. Also replicating that experiment, with superficial test-string features counterbalanced and the influence of decision processes avoided, perceptual fluency did not differ significantly between grammatical and ungrammatical strings.

5. Experiment 4

Experiment 4 sought to establish if manipulated perceptual fluency would influence familiarity and grammaticality judgments when exposure to the test-strings was limited. The experiment was the same as Experiment 3 with just one exception, consistent with Kinder et al. (2003) the test-strings were only seen during the perceptual clarification task.

5.1. Method

5.1.1. Participants

Forty participants were recruited from The University of Sussex library (13 males and 27 females). Participants ranged in age from 19 to 29 years with a mean age of 22 ($SD = 2.4$). All participants were University of Sussex students and naive to the experimental hypothesis. Participants were randomly assigned to one of two experimental conditions; 20 were trained on grammar A and 20 were trained on grammar B.

5.1.2. Procedure

The procedure was the same as Experiment 3 with the exception that test-strings were removed when participants pressed the space bar in the perceptual clarification task. As such, the strings were not available for reference when making familiarity and grammaticality judgments.

5.1.3. Materials and design

Both the materials and design were identical to those of Experiment 3.

5.2. Results

5.2.1. Learning and unconscious knowledge

The mean percentage of grammaticality judgments correct was 67 ($SE = 1.4$), significantly greater than chance (50%), $t(39) = 12.14$, $p < .001$, $d = 1.92$, and comparable to each of the previous experiments. The percentage of grammaticality judgments correct for fast clarifying strings ($M = 68$, $SE = 1.4$) was not significantly different from that for slow clarifying strings ($M = 67$, $SE = 1.9$), $t(39) = .58$, $p = .563$, $d_z = 0.09$, $CI_{.95} = -3, +4$. Accuracy was also above chance for judgments attributed to random selection ($M = 59$, $SE = 4.0$), $t(34) = 2.22$, $p = .033$, $d = .38$, indicating the presence of unconscious knowledge as measured by the guessing criterion.

5.2.2. Validating the fluency manipulation

The average identification time for fast clarifying strings ($M = 6236$ ms, $SE = 191$ ms) was significantly shorter than that for slow clarifying strings ($M = 9816$ ms, $SE = 280$ ms), $t(39) = 31.54$, $p < .001$, $d_z = 4.98$, a mean difference of 3580 ms. Five participants demonstrated unprompted awareness of the different clarification speeds.

5.2.3. The effect of decision processes on identification times

With grammaticality judgments required to be made based solely on exposure during the perceptual clarification task, consistent with Experiment 2, identification times revealed the influence of decision processes. The mean identification time for Experiment 4 ($M = 8026$ ms, $SE = 233$ ms) was significantly longer than that for Experiment 3 ($M = 6624$ ms, $SE = 213$ ms), $t(79) = 4.45$, $p < .001$, $d = .99$. The mean difference of 1404 ms ($SE = 315$ ms) was consistent with the difference observed between Experiments 1 and 2 (1502 ms). Identification times were again negatively correlated with the extremity of familiarity, as measured by absolute z-familiarity (*Mean* $r = -.06$, $SE = .02$), $t(39) = 2.77$, $p = .009$, $d = .43$, and absolute z-familiarity was greater for grammatical ($M = .90$, $SE = .01$), than ungrammatical strings ($M = .79$, $SE = .01$), $t(39) = 6.05$, $p < .001$, $d_z = .99$. Consequently, replicating the difference seen between Experiments 1 and 2, the difference in perceptual identification speed for ungrammatical minus grammatical strings was significantly greater in Experiment 4 ($M = 171$ ms, $SE = 70$ ms) than in Experiment 3 ($M = 19$ ms, $SE = 37$ ms), $t(79) = 1.92$, $p = .030$ one-tailed, $d = .43$. As with Experiment 2, the influence of decision processes on the perceptual clarification task invalidates identification times as a measure of perceptual fluency. However, in the current experiment the effect of perceptual fluency on familiarity and grammaticality judgments can still be examined based on the experimental manipulation of clarification rate.

5.2.4. The effect of clarification rate on familiarity

A 2×2 within subjects ANOVA on familiarity ratings with clarification rate (fast vs. slow) and grammaticality (grammatical vs. ungrammatical) as independent variables revealed large significant main effects of both grammaticality, $F(1,39) = 110.48$, $p < .001$, $\eta_p^2 = .74$, and of rate, $F(1,39) = 13.54$, $p = .001$, $\eta_p^2 = .26$, but no interaction between them, $F(1,39) = 1.04$, $p = .313$, $\eta_p^2 = .03$, see Fig. 3a. Unlike Experiment 3, artificially enhancing fluency was found to significantly increase the perceived familiarity of the grammar strings. However, the difference in familiarity resulting from grammaticality ($M = 18\%$, $SE = 1.7$) was substantially larger than that resulting from the fluency manipulation ($M = 2\%$, $SE = 0.6$), $t(39) = 9.25$, $p < .001$, $d_z = 1.46$.

5.2.5. The effect of clarification rate on grammaticality judgments

A 2×2 within subjects ANOVA on endorsement rate with clarification rate (fast vs. slow) and grammaticality (grammatical vs. ungrammatical) as independent variables revealed a large significant main effect of grammaticality, $F(1,39) = 147.38$, $p < .001$, $\eta_p^2 = .79$, and a medium sized

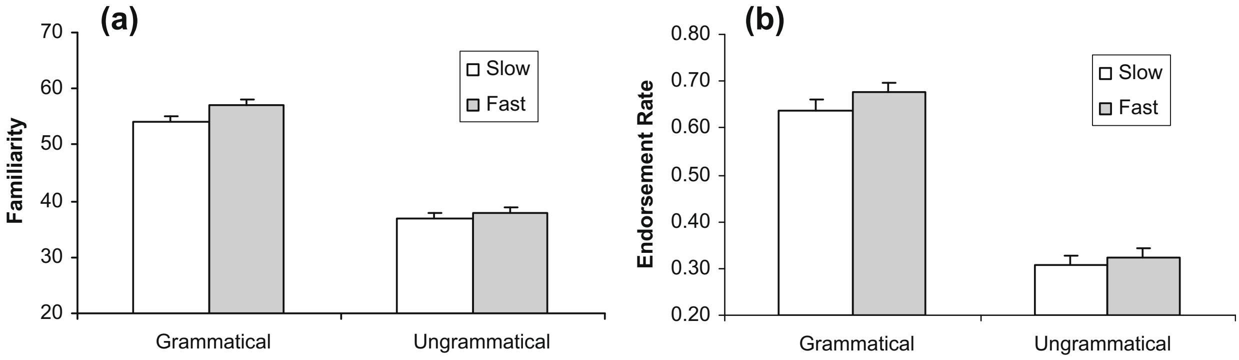

Fig. 3. Mean familiarity ratings (a) and endorsement rates (b) for grammatical and ungrammatical strings clarifying at fast and slow rates, where test-strings were seen only during the clarification task (Experiment 4). Error bars are standard errors of the difference between fast and slow rates.

significant main effect of rate, $F(1,39) = 4.23$, $p = .046$, $\eta_p^2 = .10$, but no interaction between them, $F(1,39) = .34$, $p = .563$, $\eta_p^2 = .01$, see Fig. 3b. The difference in endorsement rate resulting from grammaticality ($M = .34$, $SE = .03$) was substantially greater than that resulting from the fluency manipulation ($M = .03$, $SE = 0.1$), $t(39) = 10.08$, $p < .001$, $d_z = 1.59$. In contrast to Experiment 3 but consistent with Kinder et al. (2003), artificially enhancing fluency was found to significantly increase the likelihood of endorsing a string as grammatical; the increase in endorsement rate of 3% was the same as that achieved in the comparable experiments of that study.[11] In addition to being significant, the difference in endorsement rate for fast minus slow strings seen in Experiment 4 ($M = .03$, $SE = .01$) was significantly greater than that seen in Experiment 3 ($M = -.01$, $SE = .01$), $t(79) = 1.72$, $p = .045$ (one-tailed), $d = .47$, supporting the notion that the effect on endorsement rate was related to restricting exposure to the test-strings.

Analysis was conducted to examine if the relationship between manipulated fluency and grammaticality judgment was mediated by familiarity. The correlation between clarification rate and familiarity was significant (*Mean* $r = .05$, $SE = .01$), $t(39) = 4.02$, $p < .001$, $d = .71$. When grammaticality judgment was simultaneously regressed on familiarity and clarification rate (slow = 0, fast = 1), the mean standardized beta was significant for familiarity (*Mean* $\beta = .74$, $SE = .02$), $t(40) = 45.63$, $p < .001$, $d = 7.40$, but not for clarification rate (*Mean* $\beta = -.02$, $SE = .01$), $t(40) = 1.40$, $p = .171$, $d = -.25$. Following Baron and Kenny's (1986) procedure, these results are indicative that, as for natural differences in perceptual fluency, the influence that manipulated differences have on grammaticality judgments is mediated by familiarity.

5.3. Discussion

Experiment 4 found that when exposure to the test-strings was limited to the perceptual clarification task, artificially enhancing perceptual fluency increased both the perceived familiarity of the grammar strings and their likelihood of being endorsed as grammatical. The latter result replicates the finding of Kinder et al. (2003). In both the current experiment and the comparable experiments of Kinder et al., the fluency manipulation induced a 3% difference in endorsement rate as compared with a 33–34% difference resulting from grammaticality. Consistent with the effects observed for naturally occurring differences in fluency in Experiment 1, the influence of manipulated fluency on grammaticality judgments was mediated by familiarity. Together the results of Experiments 3 and 4 suggest that for manipulated fluency to significantly influence grammaticality judgments exposure to the test-strings, and hence alternative sources of judgment, may need to be limited.

Experiments 4 also replicated the finding from Experiment 2 that when exposure to the test-strings was restricted, identification times in the perceptual clarification task were compromised by decision processes resulting in shorter identification times for grammatical strings.

6. General discussion

This study sought to establish the extent to which perceptual fluency reflects the grammaticality of test-strings in artificial grammar learning, the degree to which it might influence grammaticality judgments, and its relationship with subjective feelings of familiarity. Perceptual fluency was found to be unrelated to grammaticality and as such is not a source of implicit knowledge in this paradigm. However, perceptual fluency derived from sources unrelated to grammaticality was found to influence responding, with that influence mediated by feelings of familiarity. This dumb influence of perceptual fluency – dumb in the sense that it does not assist the accuracy of responses – was found to be greater where reference to the test-strings was restricted.

We employed the same procedure to assess perceptual fluency as employed by Buchner (1994) and found that superficial test-string features and decision processes will have contributed to the apparent relationship between fluency and grammaticality observed in that study. Fewer

[11] Only Experiments 1 and 2 of Kinder et al. (2003) required grammaticality judgments where the test-strings included both grammatical and ungrammatical strings. The difference in endorsement rate was 3% in both of those experiments. Data provided by email (Kinder, personal communication, March 19, 2007).

letter repetitions (more letter changes), as true of ungrammatical test-strings in Buchner's Experiment 1, resulted in longer identification times. Removing test-strings before requiring grammaticality judgments, as in Buchner's Experiment 2, resulted in decision processes affecting the preceding clarification task such that ungrammatical strings were again associated with longer identification times (Experiments 2 and 4). With all superficial test-string features counterbalanced and with grammar strings present for grammaticality judgments, there was no detectable influence of decision processes and no significant difference in the perceptual fluency of grammatical and ungrammatical strings (Experiments 1 and 3).

Previous experimental studies have indicated that perceptual fluency could not play a major role in AGL (Buchner, 1994; Chang & Knowlton, 2004; Newell & Bright, 2001; Zizak & Reber, 2004). The present study is consistent with that body of work and goes further by providing strong evidence that perceptual fluency is not a source of accuracy in this paradigm. However, variations in perceptual fluency derived from sources unrelated to grammaticality were shown to influence feelings of familiarity, which in turn mediated an effect on grammaticality judgments. Kinder et al.'s (2003) finding, that artificially enhancing perceptual fluency increases the likelihood of a string being endorsed as grammatical, was replicated and the same effect demonstrated to result from naturally occurring differences in perceptual fluency. Crucially however, the effect of enhancing fluency was significantly larger when, consistent with Kinder et al.'s procedure, exposure to the test-strings was restricted to the clarification task. In contrast, where the test-strings were available for reference when making grammaticality judgments the fluency manipulation did not significantly influence responding. We contend that the reduced contribution of fluency in this condition was most likely the result of the extended opportunity to process the test-strings facilitating alternative bases for judgment. Johansson (2009) observed a similar effect on grammaticality judgments when manipulating fluency using masked priming. In that study the fluency manipulation was found to influence judgments made under a response deadline of 2000 ms but not those made under free response. Both the results of the present study and those of Johansson are consistent with results from other paradigms indicating that perceptual fluency influences decision processes only to the extent that alternative bases for judgment are limited or unavailable (Kinoshita, 2002; Whittlesea & Leboe, 2000; Willems et al., 2007).

Kinder et al. (2003) proposed that participants exploit either a fluency heuristic or a recollection heuristic depending on the task demands. They assert that the recollection heuristic is insensitive to differences in perceptual fluency and that the fluency heuristic is generally employed when making grammaticality judgments. However, evidence that the influence of perceptual fluency is greater when alternative sources of judgment are restricted provides an alternative explanation for their findings. Extended analysis of the test-strings may assist grammaticality judgments in multiple ways; permitting any conscious rules to be applied and allowing knowledge to be derived that will assist in the classification of subsequent test-strings. For example, features of a test-string that is confidently believed to be grammatical may inform the classification of subsequent strings. These processes do not apply to recognition judgments, which will consequently not benefit to the same degree from extended exposure. If perceptual fluency has a greater influence when alternative sources of judgment are limited it follows that where reference to the test-strings is restricted fluency will make a larger contribution to grammaticality judgments, as observed by Kinder et al. and in Experiment 4 of the current study. Where more time is available to process the strings then the influence of manipulated fluency on grammaticality judgments should be reduced, as observed in Experiment 3 of the current study. It also follows that if the basis for recognition judgments was sufficiently restricted, then they too should show greater reliance on perceptual fluency. Kinder et al. observed precisely this effect; where the usual cues for recognition were removed by having only new strings in the test phase, recognition judgments were influenced by the fluency manipulation. It seems that a single general mechanism, whereby perceptual fluency influences responding when veridical sources of information are limited, can thus account for the differential sensitivity to fluency manipulations without recourse to specific fluency and recollection heuristics.

6.1. The source of subjective familiarity and accuracy in AGL

The present study replicated the central findings of Scott and Dienes (2008) illustrating the essential role played by subjective familiarity in the learning of artificial grammars. Subjective ratings of familiarity were reliably predicted by the structural similarity of training-strings and test-strings (*Mean* $R = .51$), and familiarity ratings in turn strongly predicted grammaticality judgments (*Mean* $r = .71$). Participants showed awareness of exploiting familiarity to make a substantial proportion of their judgments (mean = 34%), while apparently also at times being influenced by familiarity without awareness, as indicated by familiarity continuing to predict responses reported to be selected at random. Rated feelings of familiarity were weakly predicted by perceptual fluency indicating that these ratings are distinct from simple measures of similarity. However, with perceptual fluency unrelated to grammaticality, there remains the question as to what mediates the relationship between structural similarities that are related to grammaticality and the experience of familiarity.

In principle, there is no reason why the feelings of familiarity exploited to make grammaticality judgments should be any different from those exploited in recognition judgments. A dominant paradigm for investigating recognition memory is the *remember/know* procedure developed by Gardiner (1988). Under that procedure, participants study a list of items, usually words, and then complete a recognition test containing old and new items. Each time a participant endorses an item as old they are required to report on the nature of their judgment. If their recognition is accompanied by conscious recollection of encountering the item in training they indicate the item was *remembered*. If recognition occurred without conscious recollection, as for example where a judgment is based on familiarity, then the item is to be reported as *known*.

Gardiner (1988) originally proposed that know responses are based on the same process that is responsible for repetition priming in perceptual tests. However, consistent with perceptual fluency being only weakly related to familiarity in AGL, subsequent studies in the remember/know paradigm have similarly found perceptual fluency not to be the basis of know responses (Dewhurst & Anderson, 1999; Rajaram & Geraci, 2000). Dewhurst and Anderson employed a procedure where exact repetition or category repetition was used to manipulate perceptual or conceptual fluency respectively. They demonstrated a double dissociation between the type of repetition and the facilitation of remember and know judgments. Perceptual priming increased correct remember responses without influencing know responses, and conceptual priming increased correct know responses without influencing remember responses.

Rajaram and Geraci similarly found an influence of conceptual rather than perceptual fluency. Conceptual fluency manipulated by presenting either semantically related or unrelated primes increased the number of know responses without affecting remember responses (though see Tunney and Fernie (2007) who show that the omission of a guess category in the traditional remember-know paradigm may result in a spurious dissociation between these categories).

The finding that familiarity is not substantially derived from perceptual fluency in AGL is clearly consistent with findings for recognition memory. The memory literature implicates conceptual fluency as a possible alternative, but how might this be examined within the context of AGL? Perceptual fluency relates to the ease with which the physical representation of a stimulus is identified. Conceptual fluency concerns the ease of mental operations relating to a stimulus' meaning and associated semantic knowledge (Jacoby & Dallas, 1981; Whittlesea, 1993). Where perceptual fluency will facilitate perceptual identification, conceptual fluency should facilitate conceptual categorisation. In the context of grammar strings, perceptual identification involves reading the letters making up the string. This requires categorisation at the feature level i.e. features are categorised into letters. In contrast, grammaticality judgments require categorisation at the holistic level. On this basis more conceptually fluent grammar strings should result in shorter decision times when making grammaticality judgments. If conceptual fluency were the basis of feelings of familiarity in AGL then shorter decision times would be associated with higher familiarity ratings. We did not aim to evaluate conceptual fluency in this study, and therefore make no strong claims in this regard. However, contrary to such an account, where identification times were found to reflect decision processes (Experiments 2 and 4), faster judgments were associated with the extremity of familiarity i.e. both high and low familiarity ratings. As such, if the speed of perceptual identification and conceptual categorisation are taken to measure perceptual and conceptual fluency respectively, then the results of the present study support neither as the basis of judgments in AGL.

The relationship between decision speed and familiarity ratings is more simply explained by an account that reverses the relationship between them. The *RT-Distance Hypothesis* (Ashby et al., 1994) provides such an account by essentially proposing that easier categorizations – those further from the decision boundary – are made more quickly. Thus, shorter decision times observed for high and low familiarity ratings are consistent with a decision boundary around the mean familiarity. Rather than familiarity ratings reflecting decision speeds, as implied by a fluency account, decision speeds reflect the distance from the mean familiarity. Such an account requires that the originating feelings of familiarity be derived from some source other than processing fluency. A range of alternatives have been proposed with familiarity variously derived from quantitative memory strength (Yonelinas, 1994), degree of activation (Atkinson & Juola, 1974; Mandler, 1991), or autonomic arousal associated with resource allocation (Morris, Cleary, & Still, 2008).

Table A1
Training-strings and test-strings used in all experiments.

Length	Training		Testing	
	Grammar A	Grammar B	Grammar A	Grammar B
7	XMXRTVM	VVTRMTM	XMMXRVM	VTRRRRM
7	VVTRVTM	VVTTRXM	XXRTVTM	VVRXRRM
7	VTVTRVM	VVRMTRM	XXRTTVM	XMVRXRM
7	VTTTTVM	XMTRRRM	XMMMMXM	XXRRRRM
8	VTTVTRVM	XMVTTRXM	VVTRTTVM	XMVTRXRM
8	VVTRTVTM	VVTTRXRM	XMMXRTVM	VVTTRMTM
8	VTTTTVTM	VVTRXRRM	VTTTTTVM	VVRMTRRM
8	XXRVTRVM	VVRMVRXM	XMXRTVTM	XMVTRMTM
8	VTVTRTVM	XMVRXRRM	XMXRTTVM	XMVRMTRM
8	XMMMMMXM	VTRRRRRM	XXRTTTVM	VVTTTRXM
9	XXRTVTRVM	XMVRXRRRM	XXRVTRVTM	VVRMTRRRM
9	VTVTRTTVM	VVRMVTRXM	XMXRTTTVM	VVRMVRMTM
9	XMMMXRVTM	VVTTTRMTM	VVTRTTVTM	XMVRMVRXM
9	XMMMMXRVM	XMVTRXRRM	VTTVTRTVM	VVTTRXRRM
9	XXRVTRTVM	XXRRRRRRM	XMXRVTRVM	VVTTTRXRM
9	XMMMXRTVM	VVTTRMTRM	VVTRTTTVM	XMVTTRXRM

The present study has again confirmed feelings of familiarity to be the essential source of knowledge in AGL but also demonstrates that perceptual fluency is not responsible for their relationship with grammaticality. While the relationship between conceptual fluency and grammaticality was not systematically evaluated in this study, it too would appear inconsistent with our findings. Future research might productively model responding in AGL using non-fluency based models of familiarity.

Appendix A

See Table A1.

References

Allwood, C. M., Granhag, P. A., & Johansson, H. (2000). Realism in confidence judgements of performance based on implicit learning. *European Journal of Cognitive Psychology, 12*(2), 165–188.

Ashby, F. G., Boynton, G., & Lee, W. W. (1994). Categorization response time with multidimensional stimuli. *Perception and Psychophysics, 55*(1), 11–27.

Atkinson, R. C., & Juola, J. F. (1974). Search and decision processes in recognition memory. In *Contemporary developments in mathematical psychology*. In D. H. Krantz, R. C. Atkinson, R. D. Luce, & P. Suppes (Eds.). *Learning, memory and thinking* (Vol. 1). San Francisco: Freeman.

Bailey, T. M., & Pothos, E. M. (2008). AGL StimSelect: Software for automated selection of stimuli for artificial grammar learning. *Behavior Research Methods, 40*(1), 164–176.

Baron, R. M., & Kenny, D. A. (1986). The moderator-mediator variable distinction in social psychological research: Conceptual, strategic and statistical considerations. *Journal of Personality and Social Psychology, 51*, 1173–1182.

Berry, C. J., Shanks, D. R., & Henson, R. N. A. (2008). A single-system account of the relationship between priming, recognition, and fluency. *Journal of Experimental Psychology: Learning Memory and Cognition, 34*(1), 97–111.

Brooks, L. R., & Vokey, J. R. (1991). Abstract analogies and abstracted grammars: Comments on Reber (1989) and Mathews et al. (1989). *Journal of Experimental Psychology: General, 120*(3), 316–323.

Buchner, A. (1994). Indirect effects of synthetic grammar learning in an identification task. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20*(3), 550–566.

Chang, G. Y., & Knowlton, B. J. (2004). Visual feature learning in artificial grammar classification. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 30*(3), 714–722.

Channon, S., Shanks, D. R., Johnstone, T., Vakili, K., Chin, J., & Sinclair, E. (2002). Is implicit learning spared in amnesia? Rule abstraction and item familiarity in artificial grammar learning. *Neuropsychologia, 40*(12), 2185–2197.

Cleeremans, A., & Dienes, Z. (2008). Computational models of implicit learning. In R. Sun (Ed.), *Handbook of computational cognitive modeling* (pp. 396–421). Cambridge: University Press.

Dewhurst, S. A., & Anderson, S. J. (1999). Effects of exact and category repetition in true and false recognition memory. *Memory and Cognition, 27*(4), 664–673.

Dienes, Z. (2004). Assumptions of subjective measures of unconscious mental states: Higher order thoughts and bias. *Journal of Consciousness Studies, 11*(9), 25–45.

Dienes, Z. (2008). Subjective measures of unconscious knowledge. *Progress in Brain Research, 168*, 49–64.

Dienes, Z., & Altmann, G. (1997). Transfer of implicit knowledge across domains: How implicit and how abstract? In D. C. Berry (Ed.), *How implicit is implicit learning?* (pp 107–123). London: Oxford University Press.

Dienes, Z., Altmann, G. T. M., Kwan, L., & Goode, A. (1995). Unconscious knowledge of artificial grammars is applied strategically. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21*(5), 1322–1338.

Dienes, Z., & Longuet Higgins, C. (2004). Can musical transformations be implicitly learned? *Cognitive Science, 28*(4), 531–558.

Dienes, Z., & Scott, R. B. (2005). Measuring unconscious knowledge: Distinguishing structural knowledge and judgment knowledge. *Psychological Research, 69*(5-6), 338–351.

Dulany, D. E., Carlson, R. A., & Dewey, G. I. (1984). A case of syntactical learning and judgment: How conscious and how abstract? *Journal of Experimental Psychology: General, 113*(4), 541–555.

Gardiner, J. M. (1988). Functional aspects of recollective experience. *Memory and Cognition, 16*(4), 309–313.

Higham, P. A. (1997). Dissociations of grammaticality and specific similarity effects in artificial grammar learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 23*(4), 1029–1045.

Higham, P. A. (unpublished manuscript). Dumb use of the fluency heuristic: Reliance on perceptual fluency in the absence of perceptual facilitation.

Jacoby, L. L., & Dallas, M. (1981). On the relationship between autobiographical memory and perceptual learning. *Journal of Experimental Psychology: General, 110*, 306–340.

Jacoby, L. L., & Whitehouse, K. (1989). An illusion of memory: False recognition influenced by unconscious perception. *Journal of Experimental Psychology: General, 118*(2), 126–135.

Johansson, T. (2009). In the fast lane toward structure in implicit learning: Non-analytic processing and fluency in artificial grammar learning. *European Journal of Cognitive Psychology, 21*(1), 129–160.

Johnstone, T., & Shanks, D. R. (2001). Abstractionist and processing accounts of implicit learning. *Cognitive Psychology, 42*(1), 61–112.

Kinder, A., & Assmann, A. (2000). Learning artificial grammars: No evidence for the acquisition of rules. *Memory and Cognition, 28*(8), 1321–1332.

Kinder, A., Shanks, D. R., Cock, J., & Tunney, R. J. (2003). Recollection, fluency, and the explicit/implicit distinction in artificial grammar learning. *Journal of Experimental Psychology: General, 132*(4), 551–565.

Kinoshita, S. (2002). Feeling of familiarity: Memory attribution vs. memory module. In P. Chambres, M. Izaute, & P.-J. Marescaux (Eds.), *Metacognition: Process, function and use* (pp. 79–90). Dordrecht, Netherlands: Kluwer.

Knowlton, B. J., & Squire, L. R. (1994). The information acquired during artificial grammar learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20*(1), 79–91.

Levy, D. A., Stark, C. E. L., & Squire, L. R. (2004). Intact conceptual priming in the absence of declarative memory. *Psychological Science, 15*(10), 680–686.

Lieberman, M. D., Chang, G. Y., Chiao, J., Boohheimer, S. Y., & Knowlton, B. J. (2004). An event-related fMRI study of artificial grammar learning in a balanced chunk strength design. *Journal of Cognitive Neuroscience, 16*(3), 427–438.

Lorch, R. F., & Myers, J. L. (1990). Regression analyses of repeated measures data in cognitive research. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16*(1), 149–157.

Lotz, A., & Kinder, A. (2006). Transfer in artificial grammar learning: The role of repetition information. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 32*(4), 707–715.

Mandler, G. (1991). Your face looks familiar but I can't remember your name: A review of dual process theory. In E. William, E. Hockley, & E. S. Lewandowsky (Eds.), *Relating theory and data: Essays on human memory in honor of Bennet B. Murdock*. NJ: Erlbaum.

Montgomery, D. C. (1991). *Design and analysis of experiments* (3rd ed.). New York: John Wiley & Sons.

Morris, A. L., Cleary, A. M., & Still, M. L. (2008). The role of autonomic arousal in feelings of familiarity. *Consciousness and Cognition, 17*(4), 1378–1385.

Newell, B. R., & Bright, J. E. H. (2001). The relationship between the structural mere exposure effect and the implicit learning process. *The Quarterly Journal of Experimental Psychology A: Human Experimental Psychology, 54A*(4), 1087–1104.

Norman, E., Price, M. C., Duff, S. C., & Mentzoni, R. A. (2007). Gradations of awareness in a modified sequence learning task. *Consciousness and Cognition, 16*, 809–837.

Perruchet, P., & Pacteau, C. (1990). Synthetic grammar learning: Implicit rule abstraction or explicit fragmentary knowledge? *Journal of Experimental Psychology: General, 119*(3), 264–275.

Pothos, E. M. (2007). Theories of artificial grammar learning. *Psychological Bulletin, 133*(2), 227–244.

Rajaram, S., & Geraci, L. (2000). Conceptual fluency selectively influences knowing. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 26*(4), 1070–1074.

Reber, A. S. (1967). Implicit learning of artificial grammars. *Journal of Verbal Learning and Verbal Behavior, 6*(6), 855–863.

Reber, A. S. (1969). Transfer of syntactic structure in synthetic languages. *Journal of Experimental Psychology, 81*(1), 115–119.

Reber, A. S. (1989). Implicit learning and tacit knowledge. *Journal of Experimental Psychology: General, 118*(3), 219–235.

Reber, R., Schwarz, N., & Winkielman, P. (2004). Processing fluency and aesthetic pleasure: Is beauty in the perceiver's processing experience? *Personality and Social Psychology Review, 8*(4), 364–382.
Runger, D., Nagy, G., & Frensch, P. A. (2009). Do recognition and priming index a unitary knowledge base? Comment on Shanks et al. (2003). *Journal of Experimental Psychology: Learning Memory and Cognition, 35*(2), 572–585.
Scott, R. B., & Dienes, Z. (2008). The conscious, the unconscious, and familiarity. *Journal of Experimental Psychology: Learning Memory and Cognition, 34*(5), 1264–1288.
Servan Schreiber, E., & Anderson, J. R. (1990). Learning artificial grammars with competitive chunking. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16*(4), 592–608.
Stark, C. E. L., & Squire, L. R. (2000). Title Recognition memory and familiarity judgments in severe amnesia: No evidence for a contribution of repetition priming. *Behavioral Neuroscience, 114*(3), 459–467.
Tulving, E., Schacter, D. L., & Stark, H. A. (1982). Priming effects in word-fragment completion are independent of recognition memory. *Journal of Experimental Psychology: Learning Memory and Cognition, 8*(4), 336–342.
Tunney, R. J., & Altmann, G. T. M. (2001). Two modes of transfer in artificial grammar learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 27*(3), 614–639.
Tunney, R. J., & Fernie, G. (2007). Repetition priming affects guessing not familiarity. *Behavioral and Brain Functions, 3*.
Vokey, J. R., & Brooks, L. R. (1992). Salience of item knowledge in learning artificial grammars. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 18*(2), 328–344.
Vokey, J. R., & Higham, P. A. (2005). Abstract analogies and positive transfer in artificial grammar learning. *Canadian Journal of Experimental Psychology, 59*(1), 54–61.
Wagner, A. D., Gabrieli, J. D. E., & Verfaellie, M. (1997). Title dissociations between familiarity processes in explicit recognition and implicit perceptual memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 23*(2), 305–323.
Whittlesea, B. W. A. (1993). Illusions of familiarity. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19*, 1235–1253.
Whittlesea, B. W. A., & Leboe, J. P. (2000). The heuristic basis of remembering and classification: Fluency, generation, and resemblance. *Journal of Experimental Psychology: General, 129*(1), 84–106.
Whittlesea, B. W. A., & Price, J. R. (2001). Implicit/explicit memory versus analytic/nonanalytic processing: Rethinking the mere exposure effect. *Memory and Cognition, 29*(2), 234–246.
Whittlesea, B. W. A., & Williams, L. D. (2000). The source of feelings of familiarity: The discrepancy-attribution hypothesis. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 26*(3), 547–565.
Willems, S., van der Linden, M., & Bastin, C. (2007). The contribution of processing fluency to preference: A comparison with familiarity-based recognition. *European-Journal-of-Cognitive-Psychology, 19*(1), 119–140.
Yonelinas, A. P. (1994). Receiver-operating characteristics in recognition memory: Evidence for a dual-process model. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20*(6), 1341–1354.
Zizak, D. M., & Reber, A. S. (2004). Implicit preferences: The role(s) of familiarity in the structural mere exposure effect. *Consciousness and Cognition, 13*(2), 336–362.