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Knowledge applied to new domains: The unconscious succeeds where the conscious fails

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ABSTRACT

A common view holds that consciousness is needed for knowledge acquired in one domain to be applied in a novel domain. We present evidence for the opposite; where the transfer of knowledge is achieved only in the absence of conscious awareness. Knowledge of artificial grammars was examined where training and testing occurred in different vocabularies or modalities. In all conditions grammaticality judgments attributed to random selection showed above-chance accuracy (60%), while those attributed to conscious decisions did not. Participants also rated each string's familiarity and performed a perceptual task assessing fluency. Familiarity was predicted by repetition structure and was thus related to grammaticality. Fluency, though increasing familiarity, was unrelated to grammaticality. While familiarity predicted all judgments only those attributed to random selection showed a significant additional contribution of grammaticality, deriving primarily from chunk novelty. In knowledge transfer, as in visual perception (Marcel, 1993), the unconscious may outperform the conscious.

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1. Introduction

One of the supposed advantages of conscious knowledge is its flexibility, the potential for it to be applied in novel ways and to novel situations (e.g. Baars, 1988). In contrast, unconscious knowledge is generally held to be inflexible and limited in its application to the context in which it was acquired (Shiffrin & Schneider, 1977). However, implicit learning research has challenged this characterisation of unconscious knowledge. The transfer of knowledge from one context to another has been demonstrated where the initial learning was implicit (e.g. Brooks & Vokey, 1991; Reber, 1969). Still more remarkable, though subject to greater debate, is the evidence that such knowledge may remain unconscious when applied in the new domain (Dienes & Altmann, 1997; Reber, 1989). The present study helps to resolve this issue, providing strong evidence that unconscious knowledge transfer is a reality while also helping to clarify both the basis of the knowledge itself and the manner in which it is experienced.

Artificial grammar learning (AGL) has been a useful paradigm for the investigation of implicit learning (Pothos, 2007; Reber, 1989). In a typical AGL experiment participants are exposed to letter strings generated using a complex set of rules, referred to as a grammar. Most often the strings are presented under the guise of a short-term memory task with participants unaware of their rule-based nature. At test, after being informed of the existence of rules, participants judge which of a new set of strings are grammatical – typically discriminating them with above-chance accuracy (e.g. Reber, 1989). In the transfer variant of AGL, training strings are presented in one alphabet or modality and test strings are presented in another e.g. training on sequences of tones and testing on strings of letters. Classification accuracy under transfer conditions is

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typically lower than that for the non-transfer task but frequently remains above-chance (e.g. Altmann, Dienes, & Goode, 1995; Gomez, Gerken, & Schvaneveldt, 2000; Knowlton & Squire, 1996; Tunney & Shanks, 2003). There has been considerable research examining the basis of transfer knowledge but comparatively little addressing the question of how, or even if, such knowledge is subjectively experienced.

There is extensive evidence that judgments in the standard, non-transfer, AGL task are guided by knowledge of fragments, or chunks, of the training strings (e.g. Dulany, Carlson, & Dewey, 1984; Johnstone & Shanks, 2001; Knowlton & Squire, 1996; Servan Schreiber & Anderson, 1990), and also in part by knowledge of whole training exemplars (Vokey & Brooks, 1992). The transfer of knowledge to a novel vocabulary requires a mapping between elements based either on the frequency of their occurrence in different locations or on the pattern of repeating elements. While transfer can be achieved based solely on frequency information (Tunney & Altmann, 2001), where strings contain repeating elements it is repetition structure that is found to be the primary basis for transfer (Brooks & Vokey, 1991; Gomez et al., 2000; Lotz & Kinder, 2006; Vokey & Higham, 2005). Repetition structure can be either *adjacent* (Mathews & Roussel, 1997) or *global* (Vokey & Brooks, 1992). Adjacent repetition structure reflects whether each element is the same (1) or different (0) to the immediately preceding element e.g. the adjacent repetition structure of VTVVT is 0010. Global repetition structure reflects whether any element is the same as any other element e.g. the global repetition structure of the same string is 12112.

The fact that responding in AGL reflects the structural similarities between training and test strings does not in itself tell us how such knowledge is experienced. Here an important distinction is that between *objective structural similarities*, as captured by measures such as chunk strength and repetition structure, and *subjective feelings*, as captured in the reported experience of familiarity. There is substantial evidence indicating that the knowledge acquired in AGL, and in implicit learning more generally, is experienced primarily as familiarity, defined as the subjective feeling of oldness elicited by a stimulus (Dienes, Scott, & Wan, in press; Higham, 1997; Johnstone & Shanks, 2001; Kinder & Assmann, 2000; Norman, Price, Duff, & Mentzoni, 2007; Scott & Dienes, 2008, in press-b). Scott and Dienes further demonstrated that consistency in the repetition structure of training and test strings contributes to the experience of familiarity in AGL. It follows that knowledge under transfer conditions, where repetition structure is known to be the primary structural basis for judgments, may also be experienced as differential feelings of familiarity, though this has yet to be directly tested. In the memory literature familiarity has been proposed to result from perceptual processing fluency, that is the ease with which a stimulus is initially perceived (Jacoby & Dallas, 1981; Whittlesea & Williams, 2000). While a number of studies indicate that perceptual fluency is not the basis of responding in normal AGL conditions (e.g. Newell & Bright, 2001; Scott & Dienes, 2009a; Zizak & Reber, 2004), the influence of fluency has been found to be greater where other sources of information are restricted (Johansson, 2009; Scott & Dienes, 2009a). Given that transfer conditions eliminate most of the normal cues for classification, fluency could feasibly make a greater contribution in this context. Again this has yet to be tested.

Central to the question of whether knowledge transfer occurs unconsciously is whether the judgement of grammaticality itself constitutes conscious knowledge, or is associated with conscious feelings such as familiarity, and whether the structural knowledge underlying the judgment is conscious. We addressed these questions in the current study by evaluating the contribution of feelings of familiarity under a variety of transfer contexts. In addition, participants were required to indicate what they believed to be the basis for each grammaticality judgment: random selection, intuition, familiarity, rules, or recollection. Based on subjective measures of consciousness (Dienes, 2008), these categories can be used to differentiate the conscious status of both judgment and structural knowledge (see Dienes & Scott, 2005). In the present study there is deemed to be unconscious knowledge of the grammar where participants show above-chance accuracy in their grammaticality judgments while reporting having no knowledge and having selected their answers at random; this is a variation of the guessing criterion of unconscious knowledge (Cheesman & Merikle, 1986). Critics of the guessing criterion argue that a spurious assessment of unconscious knowledge may result if participants only report possessing knowledge above some threshold of certainty (e.g. Reingold & Merikle, 1990). While we did not set out to address this issue, as will become apparent the pattern of results observed in the present study is not subject to this criticism.

In summary, we examine for the first time the contribution made by feelings of familiarity and processing fluency in an AGL transfer task, and find strong evidence that transfer can be achieved unconsciously.

2. Method

2.1. Participants

Ninety University of Sussex students (20 male and 70 female) participated in the study in exchange for course credits. Participants ranged in age from 18 to 42 years with a mean age of 23 (SD = 5.7). All participants were naive to the experimental hypothesis and were randomly assigned to experimental condition.

2.2. Materials

Two finite state grammars were used to generate grammar strings between seven and nine characters in length. Both grammars, taken from Reber (1969) and Scott and Dienes (2008), use the same letter set (M, T, V, R and X) and contain the same set of valid starting bigrams and final letters. Training sets comprised sixteen strings (from the appropriate

grammar) repeated three times in random orders. The test set comprised a combination of sixteen strings from each grammar (that had not been seen during training) presented twice in random order. There was the same number of strings of each length in both training sets and the proportion of strings of each length was the same for training and test sets. Training and test strings were converted to different forms to create the three transfer conditions: (1) *letter–letter* where both training and test strings consisted of sequences of letters but where the letters used differed between training and test; (2) *note–letter* where training strings consisted of sequences of musical notes and test strings were sequences of letters; and (3) *note–symbol* where training strings were sequences of notes and test strings were sequences of novel symbols. These three conditions were chosen in order to test transfer within the same modality (letter–letter), transfer between modalities (note–letter), and transfer between modalities where the target stimuli were novel (note–symbol). For note sequences, each note was played for 300 ms with a 300 ms delay between notes. Note sequences were played via headphones with the volume set to be comfortable by each participant. Letter and symbol 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°. Grammar strings in their original letter form and the mapping between letters, notes, and symbols for each condition are given in the Appendix.

2.3. Procedure

2.3.1. Training stage

Participants were instructed to memorise each of a sequence of 48 strings of either notes or letters depending on the condition they were assigned to. Participants memorising note sequences were asked to silently repeat each sequence in the 5 s delay between the note strings. Participants memorising letter sequences saw each string for 5 s followed by a blank screen for 5 s; they were supervised and required to write down what they could remember of each string while the blank screen was present. The presentation order of both training and test strings was separately randomised for each participant.

2.3.2. Test stage

Participants were informed that the order of letters or notes in the training strings had obeyed a complex set of rules, and that they were to classify a new set of strings exactly half of which would obey the same rules. Participants were informed that the test strings would take a different form to those seen in training: letter strings made from a different letter set, letter strings in place of sequences of notes, or symbol strings in place of sequences of notes. For each trial the test string was initially presented as part of a timed perceptual clarification task to assess processing fluency. Participants were advised to press the space bar the moment that they were able to make out all the letters or symbols in a string. A fixation cross provided a two second warning that clarification was about to commence. Pixels were then removed from random locations within a masking rectangle at a rate of 0.1% per screen refresh (16.67 ms) until the space bar was pressed. At this point the string fully clarified and remained present for the subsequent judgements.

After the clarification task participants were asked: (1) to rate how familiar the string felt to them on a scale from 0 to 100 (0 = not at all familiar, 100 = completely familiar); (2) to judge the string's grammaticality (grammatical, yes or no); (3) to rate their confidence in their judgment on a scale from 50 to 100 (where 50 = 50:50 chance of being right or wrong, 100 = complete certainty); and (4) to indicate what they believed to be the basis for their grammaticality judgment (random selection, intuition, familiarity, rules, or recollection). These *decision strategies* were defined as follows: random selection – you had no confidence and 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 but could not say why it was familiar or unfamiliar; 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; recollection – if you answered 'Yes' it was because you specifically recall encountering a sequence of stimuli in training that resembled part or all of the present string. If you answered 'No' it was because you are certain that you didn't encounter any stimuli resembling the current one.

2.4. Design

The two grammar design of Dienes and Altmann (1997) was employed with half the participants trained on grammar A and half on grammar B. At test all participants classified the same test strings exactly half of which conformed to each grammar. In this way the non-grammatical test strings for one group were grammatical for the other group. Analysis was collapsed across grammar, thus ensuring that all test string features were counterbalanced across grammatical status. This counterbalancing was important for the fluency analyses and also eliminated the need for an untrained control group.

The key independent variables were: (1) transfer condition, between subject (letter–letter vs. note–letter vs. note–symbol), (2) grammatical status, within subject (grammatical vs. ungrammatical), and (3) decision strategy, within subject (random selection vs. intuition, vs. familiarity vs. rules vs. recollection). The main dependent variables of interest were (a) identification time, (b) grammaticality judgment, and (c) subjective familiarity rating. Note, the term *grammatical status* is used to refer to the objective grammaticality of a string while *grammaticality judgment* is used to refer to participants' subjective assessment of whether they believe a given string is grammatical.

Table 1
Means for the ANOVA examining percentage of grammaticality judgments correct by transfer condition and decision strategy.

	N	Random	Intuition	Familiarity	Rules	Recollection
Letter–Letter	12	58 (5.7)	45 (4.7)	52 (3.7)	57 (2.8)	49 (8.8)
Note–Letter	16	66 (5.8)	51 (3.7)	46 (2.0)	54 (5.6)	55 (8.0)
Note–Symbol	15	59 (4.3)	53 (2.9)	46 (4.5)	37 (7.4)	50 (8.4)
Total	43	62 (3.0)	50 (2.1)	48 (2.0)	49 (3.6)	51 (4.7)

Note. Decision strategy is a within subject variable. As such, analyses include only those subjects using all the strategies assessed in a given comparison. Consequently, the means and degrees of freedom differ marginally depending on the number of strategies being compared e.g. the ANOVA contrasting all five strategies necessarily includes fewer cases than the *t*-tests examining them individually.

3. Results

3.1. Learning and the conscious status of transfer knowledge

The percentage of grammaticality judgments correct was 53 (SE = .79), significantly above-chance (50%), $t(89)$ = 3.20, p = .002, d = .40, indicating that learning took place and transfer was successful.[1] An ANOVA examining percentage correct by decision strategy and transfer condition revealed a significant main effect of decision strategy, $F(4,160)$ = 2.86, p = .025, η_p^2 = .07, but no significant main effect of transfer condition, $F(2,40)$ = 1.03, p = .365, η_p^2 = .05, or significant interaction between them, $F(8,160)$ = 1.06, p = .396, η_p^2 = .05, see Table 1. There was similarly no significant effect of transfer condition when percentage correct was examined collapsing across decision strategy, $F(2,87)$ = .393, p = .676, η_p^2 = .01. As the nature of responses did not differ significantly between transfer conditions subsequent analysis collapses across them.

Examining the percentage correct by decision strategy revealed that only grammaticality judgments attributed to random selection were significantly more accurate than chance (M = 60, SE = 2.16), $t(77)$ = 4.57, p < .001, d = .52. In contrast to performance under standard conditions (Scott & Dienes, 2008), the accuracy of grammaticality judgments attributed to random selection (M = 60, SE = 2.16), was significantly greater than that for judgments attributed to non-random strategies (M = 52, SE = .98), $t(77)$ = 3.59, p = .001, d_z = .40.[2] This indicates that the accuracy observed under these transfer conditions arose predominantly, if not exclusively, from unconscious knowledge; where participants believed they were applying knowledge, as indicated by attributing their grammaticality judgments to intuition, familiarity, rules, or recollection, they performed no better than chance. The percentage of grammaticality judgments attributed to each decision strategy was: Random (M = 17, SE = 1.7), Intuition (M = 33, SE = 1.9), Familiarity (M = 29, SE = 1.9), Rules (M = 10, SE = 1.3), and Recollection (M = 11, SE = 1.3).

3.2. The influence and basis of feelings of familiarity

Consistent with findings under non-transfer conditions (Scott & Dienes, 2008), the reported feelings of familiarity significantly predicted grammaticality judgments (*Mean r* = .66, SE = .02), $t(89)$ = 34.65, p < .001, d = 3.67; strings rated more familiar were more likely to be classified as grammatical. Feelings of familiarity were also significantly related to the objective grammatical status of the strings (*Mean r* = .07, SE = .02), $t(89)$ = 4.18, p < .001, d = .47. Grammatical strings were experienced as more familiar hence the influence of familiarity will have contributed to accuracy. However, the relationship between familiarity and grammatical status under the transfer conditions of the present study (r = .07) was substantially weaker than previously observed under standard (non-transfer) conditions (r = .40, Scott & Dienes, 2008); this may account for the reduced accuracy generally observed in transfer tasks.

Analysis employing multiple regression was conducted to examine the types of structural similarity which most contribute to feelings of familiarity in the AGL transfer task.[3] This analysis assess the independent contribution made by: associative chunk strength (ACS), the mean frequency with which bigrams and trigrams contained within a test string appeared in training; novel chunk proportion (NCP), the proportion of bigrams and trigrams within a test string that did not appear in training; adjacent repetition proportion (ARP), the maximum proportion of a test string's adjacent repetition structure that appeared in training; and global repetition proportion (GRP), the maximum proportion of a test string's global repetition structure that appeared in training. These measures were selected to represent the three types of structural similarity most commonly examined in the AGL literature, namely, fragment frequency (ACS), chunk novelty (NCP), and repetition structure (ARP and GRP). They are also the same measures previously assessed in relation to subjective familiarity under non-transfer conditions (Scott & Dienes, 2008). Consistent with the established importance of repetition structure in transfer, the only measure to significantly predict

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[1] A test was conducted to evaluate the possibility that the knowledge expressed might have arisen from test-phase learning. The accuracy of responses in the second pass through the test-strings (M = 52%, SE = .94) was non-significantly lower than that in the first pass (M = 53%, SE = .94), t(89) < 1. The trend is opposite to that predicted by test-phase learning and thus supports the conclusion that the knowledge expressed was transferred between domains.

[2] In order to establish that the finding had not been unduly influenced by response bias, the same analysis was conducted using d' in place of percentage correct. The same significant difference was observed; responses attributed to random selection (M = .29, SE = .06) showed significantly greater sensitivity than those attributed to non-random strategies (M = .09, SE = .05), $t(77)$ = 2.47, p = .016, d_z = .28.

[3] All reported multiple regression analyses adhere to the individual regression equation method recommended by Lorch and Myers (1990), ensuring that within subject predictors are tested against the appropriate error terms.

Table 2
Mean standardised coefficients for familiarity simultaneously regressed on all structural similarity measures.

Measure	M	SE
ACS	0.02	0.05
NCP	−0.07	0.05
ARP	−0.15[*]	0.02
GRP	0.08[*]	0.02

Note. df = 89. ACS (associative chunk strength), NCP (novel chunk proportion), ARP (adjacent repetition proportion), GRP (global repetition proportion).
[*] p < .01.

Table 3
Mean standardised coefficients for each structural similarity measure where grammaticality judgment was regressed on familiarity and that measure.

Measure	Attributed to random selection			Attributed to non-random strategies		
	N	M	SE	N	M	SE
ACS	64	0.08	0.05	90	0.00	0.01
NCP	64	−0.13[*]	0.06	90	0.00	0.01
ARP	57	0.06	0.04	90	0.01	0.01
GRP	61	0.01	0.04	90	−0.02	0.01

Note. ACS (associative chunk strength), NCP (novel chunk proportion), ARP (adjacent repetition proportion), GRP (global repetition proportion).
[*] p < .05.

higher familiarity for grammatical strings was GRP, see Table 2.[4] Thus, under transfer conditions the extent to which the global repetition structure of a test string matches that of the training strings contributes to how familiar it will feel and hence its likelihood of being endorsed as grammatical. While ARP was also significantly related to familiarity, this was in the wrong direction to result in higher familiarity for grammatical strings; we have no clear explanation for this anomaly.

Processing fluency was also assessed for its ability to influence feelings of familiarity and hence grammaticality judgments. Shorter RTs in the perceptual clarification task, indicating greater processing fluency, weakly predicted both familiarity ratings (*Mean* $r = -.04$, $SE = .02$), $t(89) = 2.49$, $p = .015$, $d = .26$, and grammaticality judgments (*Mean* $r = -.03$, $SE = .01$), $t(89) = 2.29$, $p = .024$, $d = .23$. When grammaticality judgement was simultaneously regressed on both RT and familiarity, familiarity made a significant contribution (*Mean* $\beta = .66$, $SE = .02$), $t(89) = 34.91$, $p < .001$, $d = 3.67$, while RT did not (*Mean* $\beta = -.01$, $SE = .01$), $t(89) = -1.07$, $p = .288$, $d = .10$. These three analyses meet the requirements of Baron and Kenny (1986) test for mediation and indicate that the influence fluency had on grammaticality judgments was mediated by familiarity. That is to say that greater perceptual fluency caused strings to be experienced as more familiar and that this in turn increased their likelihood of being endorsed as grammatical. Crucially however, RTs for grammatical strings ($M = 8106$, $SE = 1752$) were not significantly shorter than those for ungrammatical strings ($M = 8078$, $SE = 1791$), $t(89) = .82$, $p = .413$, $d_z = .09$, indeed they were non-significantly longer (*M. Diff.* = 29 ms, $CI_{.95} = -40, + 98$). This indicates that fluency was unrelated to grammatical status and its influence could therefore not have been a source of accuracy.

3.3. The differential bases of conscious and unconscious knowledge

The bases for grammaticality judgments attributed to random selection and those attributed to non-random strategies were contrasted. Simultaneous multiple regression was used to evaluate the unique contribution made by each of familiarity and grammatical status to participants' grammaticality judgments. The contribution of familiarity was significant for all decision strategies but was significantly smaller for grammaticality judgments attributed to random selection (*Mean* $\beta = .30$, $SE = .06$) than for those attributed to non-random strategies (*Mean* $\beta = .66$, $SE = .03$), $t(60) = 5.62$, $p < .001$, $dz = .72$. In contrast, the contribution of grammatical status was significantly greater for grammaticality judgements attributed to random selection (*Mean* $\beta = .13$, $SE = .05$) than for those attributed to non-random strategies (*Mean* $\beta = .00$, $SE = .01$), $t(60) = 2.34$, $p = .023$, $dz = .30$, and only reached significance for those attributed to random selection, $t(60) = 2.46$, $p = .017$, $d = .34$. While the effect sizes for these analyses are small, they suggest that the grammatical status of strings only made a significant contribution over and above familiarity when participants believed they were selecting their grammaticality response at random.

Multiple regression was further used to assess the source of the additional contribution relating to grammatical status observed in random attributions. The contribution to grammaticality judgments made by each of the four structural similarity measures was separately assessed while controlling for the contribution of familiarity.[5] Table 3 shows the resulting standardised coefficients for grammaticality judgments attributed to random selection and those attributed to non-random

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[4] Note, GRP was the only measure to significantly predicted higher familiarity ratings despite the relationship between grammaticality and GRP ($r = .40$) being considerably weaker than that between grammaticality and other measures e.g. ACS ($r = .90$).

[5] Power was insufficient to conduct a simultaneous analysis of the contribution of all four structural similarity measures.

strategies. Controlling for familiarity, novel chunk proportion (NCP) made a significant contribution to judgments attributed to random selection but not those attributed to non-random strategies. The contribution of NCP was also significantly greater for random attributions (*Mean β* = −.13, *SE* = .06) than for non-random strategies (*Mean β* = .00, *SE* = .02), *t*(63) = 2.11, *p* = .039, *dz* = .28. While the effect is small, the result suggests that the additional accuracy shown in grammaticality judgments attributed to random selection may arise, at least in part, from a greater sensitivity to chunk novelty.

4. Discussion

This study investigated the nature of knowledge exhibited in an AGL transfer task, where training and testing occurred in different vocabularies or modalities. The contribution of feelings of familiarity and processing fluency were examined and the extent to which the knowledge exploited was conscious or unconscious was assessed. The results were not found to differ depending on whether transfer occurred between different modalities or within the same modality using different vocabularies. This stands in contradiction to the theoretical position that statistical learning is modality specific and should hence only occur within the same modality (cf. Conway & Christiansen, 2006).

The contribution that familiarity made to responding replicated findings for the non-transfer task (Scott & Dienes, 2008). Feelings of familiarity strongly predicted grammaticality judgments (*r* = .66) and continued to do so when participants attributed those judgments to random selection. Attributing responses to random selection indicates that for those judgments participants are unaware of using any strategy to make their decision, this includes the relative familiarity of the test string. Thus, the results suggest that feelings of familiarity may, in some instances, influence grammaticality judgments in the absence of conscious awareness. Fluency exerted a weak influence on responding (*r* = .03) which was mediated by familiarity. This weak influence replicated that observed in non-transfer conditions under circumstances where the time available to process the stimuli was restricted (Kinder, Shanks, Cock, & Tunney, 2003; Scott & Dienes, 2009a). However, processing fluency was found not to be related to grammatical status and as such could not have been a source of transfer knowledge. The finding that fluency is not the source of accurate grammaticality judgments under transfer conditions is consistent with the wider body of evidence under non-transfer conditions (Buchner, 1994; Newell & Bright, 2001; Scott & Dienes, 2009a; Zizak & Reber, 2004).

Consistent with the established importance of repetition structure in transfer performance the only measure found to reliably increase the familiarity of grammatical strings was global repetition proportion (GRP). Similar patterns of repetition, even when training and test stimuli were presented in different modalities, elicited feelings of familiarity and consequently influenced responding. For the materials used, the correlation between GRP and grammatical status was .40, and will consequently have contributed to a relationship between familiarity and grammaticality. However, while familiarity was greater for grammatical strings the relationship between them (*r* = .07) was substantially weaker than that observed in non-transfer conditions (*r* = .40, Scott & Dienes, 2008) where factors other than GRP also contribute to familiarity. This may account for the reduced accuracy generally observed in transfer tasks.

The relationship between familiarity and grammaticality judgments was significantly greater for judgments attributed to the use of non-random strategies than those attributed to random selection. However, the weak relationship between familiarity and grammatical status was insufficient to result in above-chance accuracy in those judgments. Only for random attributions, where familiarity contributed less but grammatical status made an independent contribution, was significant accuracy achieved (60%). A potential basis for the additional accuracy was identified to be chunk novelty which, controlling for familiarity, made a significant contribution to judgments attributed to random selection but not those attributed to non-random strategies. While conscious feelings of familiarity revealed sensitivity to global repetition structure, only unconscious knowledge revealed an additional sensitivity to the presence of novel bigrams and trigrams. It should however be noted that while the relevant effects were significant, the effect sizes were small. Given that training and test strings appeared in different vocabularies or modalities, the observed sensitivity to novel chunks will have necessitated a mapping between the stimulus sets; this appears to have been achieved unconsciously.

The reason why knowledge might be expressed predominantly in the random attributions is unclear but could potentially arise from the application of conscious strategies changing the nature of experience. For example, a weak behavioural bias, perhaps based upon chunk novelty, might be obscured by the attempt to apply a rule or even to access conscious feelings of intuition. Such an account is consistent with findings that accuracy in identifying words presented subliminally can be above-chance when participants adopt a passive strategy of allowing the word to 'pop into their head' while remaining at chance when they attempt to 'look carefully' (Snodgrass, Shevrin, & Kopka, 1993; Vanselst & Merikle, 1993). Responding based on random selection in the present study could represent a passive approach equivalent to this 'pop-out' strategy.

The same account is also consistent with some findings arising from the unconscious thought literature. Unconscious Thought Theory (Dijksterhuis, Bos, Nordgren, & van Baaren, 2006) holds that complex decisions may benefit more from a period of 'unconscious thought' than from an equivalent period of conscious deliberation. For example, Dijksterhuis, Bos, van der Leij, and van Baaren (2009) found that in predicting the outcome of soccer matches participants with greater expertise made more accurate judgments after a period of unconscious thought than when judgments were made either immediately or after conscious deliberation. That study also found evidence that this advantage resulted from the more appropriate weighting of information. While attempts to replicate the unconscious advantage have been mixed (see Acker, 2008 for a meta-analysis) there is evidence that differences may arise from conscious deliberation on one's first impressions

impairing decision quality rather than from unconscious thought enhancing decision making (Waroquier, Marchiori, Klein, & Cleeremans, in press). In the present study there was no opportunity for unconscious thought, however, responses attributed to non-random strategies will reasonably have involved greater deliberation which may hence have been the source of reduced accuracy. It may be informative to examine whether the neurological locus of judgments employing the alternate strategies differs in ways similar to that observed for other bases of judgement in AGL (cf. Pothos & Wood, 2009).

The pattern of results observed in the present study is not subject to the usual criticisms levelled at subjective measures of unconscious knowledge. Given that accuracy was absent when participants attributed their grammaticality judgments to conscious knowledge, the unconscious knowledge apparent in the accuracy of judgments attributed to random selection cannot be ascribed to a reporting bias i.e. a failure to report low levels of conscious knowledge. To conclude, we find clear evidence that knowledge transfer can occur unconsciously and hence that consciousness is not necessary for the flexible application of knowledge. Furthermore, as previously identified for visual perception (Marcel, 1993) and for motor skills (Reed, McLeod, & Dienes, 2010), we find that the unconscious can at times outperform the conscious.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.concog.2009.11.009.

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