Consciousness and Cognition 21 (2012) 865–874

Contents lists available at SciVerse ScienceDirect

Consciousness and Cognition

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

Conscious and unconscious thought in artificial grammar learning

Andy David Mealor *, Zoltan Dienes

School of Psychology, University of Sussex, Falmer, Brighton BN1 9QH, UK
Sackler Centre for Consciousness Science, University of Sussex, Falmer, Brighton BN1 9QH, UK

ARTICLE INFO

Article history:
Received 28 September 2011
Available online 1 April 2012

Keywords:
Implicit learning
Unconscious thought
Subjective measures
Artificial grammar learning

ABSTRACT

Unconscious Thought Theory posits that a period of distraction after information acquisition leads to unconscious processing which enhances decision making relative to conscious deliberation or immediate choice (Dijksterhuis, 2004). Support thus far has been mixed. In the present study, artificial grammar learning was used in order to produce measurable amounts of conscious and unconscious knowledge. Intermediate phases were introduced between training and testing. Participants engaged in conscious deliberation of grammar rules, were distracted for the same period of time, or progressed immediately from training to testing. No differences in accuracy were found between intermediate phase groups acting on decisions made with meta-cognitive awareness (either feeling-based intuitive responding or conscious rule- or recollection-based responding). However, the accuracy of guess responses was significantly higher after distraction relative to immediate progression or conscious deliberation. The results suggest any beneficial effects of 'unconscious thought' may not always transfer to conscious awareness.

1. Introduction

A number of recent studies by Dijksterhuis and colleagues have focused on Unconscious Thought Theory (UTT; e.g.: Bos, Dijksterhuis, & van Baaren, 2008, 2011; Dijksterhuis, 2004; Dijksterhuis, Bos, Nordgren, & van Baaren, 2006; Dijksterhuis & van Olden, 2006; Nordgren, Bos, & Dijksterhuis, 2011; Strick, Dijksterhuis, & van Baaren, 2010; see also Ham & van den Bos, 2010, 2011; Ham, van den Bos, & van Doorn, 2009; Handley & Runnion, 2011; Lerouge, 2009; Usher, Russo, Weyers, Brauner, & Zakay, 2011). UTT presents the counterintuitive yet appealing notion that unconscious processing leads to improved performance in complex decision making tasks compared to immediate choice or rigorous conscious deliberation (the deliberation without attention hypothesis; Dijksterhuis & Nordgren, 2006). In a standard deliberation without attention UTT study, participants are required to choose the most desirable alternative from a number of options. For example, Dijksterhuis (2004, experiment 1) asked participants to choose the most desirable of four apartments. Each was described by 48 pieces of information with differing numbers of positive and negative attributes. Participants then were asked to think carefully about their decision ("conscious thought"), were given a distracter task for the same period of time ("unconscious thought"), or made an immediate choice. It was found that people in the distraction condition were more likely to choose, or rate as most desirable, the apartment with most positive attributes than those in the other conditions. Furthermore, people in the distraction condition were more likely to attribute their decision to a 'global' judgement whereas careful deliberation thinkers based their decision on 'one or two specific attributes'.

In a meta-analysis of 92 studies, Strick, Dijksterhuis, Bos, van Sjoerdsma, and Baaren (2011) argued that as these decision making tasks are complex, unconscious thought leads to superior decision making quality than conscious thought. According

* Corresponding author at: School of Psychology, University of Sussex, Falmer, Brighton BN1 9QH, UK. Fax: +44 1273 678058.
E-mail address: a.d.mealor@sussex.ac.uk (A.D. Mealor).

1053-8100/$ - see front matter
http://dx.doi.org/10.1016/j.concog.2012.03.001

to the deliberation without attention hypothesis, unconscious consolidation of stimuli occurs during the distraction period between information acquisition and decision making. This weights salient aspects of the stimuli in a 'naturalistic' manner. Immediate decision making does not give enough time for this unconscious processing to occur. Due to its precision, conscious deliberation leads to the most effective decision making when the amount of information to account for is relatively small and its efficacy deteriorates with increasing complexity as capacity becomes overloaded. However, the UTT conclusion remains controversial. For example, Waroquier, Marchiori, Klein, & Cleeremans, 2009 conducted impression formation experiments using the UTT paradigm and found (with high statistical power) that immediate deciders and distracted participants made the same quality of decision, implying the decision had been made during information acquisition. That is, there was no evidence of unconscious deliberation without attention during distraction. Furthermore, they concluded that too much conscious rumination deteriorates the quality of an initial decision. A number of other studies have also failed to replicate any beneficial effect of deliberation without attention or have offered alternative explanations of the phenomenon, including the notion that a small amount of conscious processing (allowed for in the distraction condition) is better than more, or excessive, conscious processing (e.g.: Aczel, Lukacs, Komlos, & Aitken, 2011; Calvillo & Penaloza, 2009; Lassiter, Lindberg, Gonzalez-Vallejo, Bellezza, & Phillips, 2009; Newell, Wong, Cheung, & Rakow, 2009; Payne, Samper, Bettman, & Luce, 2009; Queen & Hess, 2010; Thorsteinson & Withrow, 2009; Waroquier, Marchiori, Klein, & Cleeremans, 2010; Waroquier et al., 2009; see also Gonzalez-Vallejo, Lassiter, Bellezza, & Lindberg, 2008 for a critical review of UTT. Contrast, however, Strick et al., 2011, who respond to some of these criticisms).

While the theory of unconscious thought might be appealing, replication has been sporadic even in high powered studies (and even taking into account the moderators identified by Strick et al., 2011). Dijksterhuis and Nordgren (2006) propose that intuition may be the product of unconscious thought and there is a broad consensus that intuition is based on unconscious processes or knowledge which, according to dual-process accounts, differs qualitatively from conscious, deliberative thinking (for recent reviews see Dienes & Seth, 2010; Evans, 2008; Evans, 2010, Dienes, 2012; Glöckner & Witteman, 2010; see also Dienes & Scott, 2005). But it has not been shown that standard UTT tasks necessarily use unconscious knowledge anyway. As of yet there have not been any studies conducted of unconscious thought that use a paradigm demonstrably eliciting both conscious and unconscious knowledge of the acquired information. If there is a true benefit of distraction in allowing unconscious thought, one may expect this to be reflected in decisions based on unconscious knowledge more so than conscious knowledge. Furthermore, Acker (2008) suggests the possibility that "[the standard UTT] experimental approach is not very suitable to demonstrate the unconscious thought effect reliably" (p. 301; see also Gonzalez-Vallejo et al., 2008; Waroquier et al., 2009). To this end, we employ artificial grammar learning (AGL; Reber, 1967) to investigate possible advantages of distraction in decision making with a clear unconscious component.

Artificial grammar learning is the task used by Reber (1967) when he coined the term "implicit learning" to refer to the incidental acquisition of unconscious knowledge. Artificial grammars generate strings of letters according to a finite-state rule system (Knowlton & Squire, 1994) and typically AGL involves a training phase and a testing phase. In the training phase of the experiment, participants are exposed to strings of letters generated, unbeknownst to the participants, by the grammar in question. They are then informed of the existence of rules governing the strings before proceeding to the testing phase where they classify novel strings as grammatical (obey the rules) or ungrammatical (violate the rules). During initial exposure to the training set of strings, some knowledge of the rules underlying the grammar is thought to be acquired unconsciously as performance is often reliably above chance yet participants typically have difficulty articulating rules of the grammar (e.g.: Reber, 1969; Reber & Allen, 1978). A large body of evidence using various subjective methods to assess awareness suggests both conscious and unconscious knowledge of grammar structure is acquired during AGL (e.g.: Dienes, Altmann, Kwan, & Goode, 1995; Dienes & Scott, 2005; Dienes & Seth, 2010; Mealor & Dienes, 2012; Persaud, McLeod, & Cowey, 2007; Scott & Dienes, 2008; Scott & Dienes, 2010a; Scott & Dienes, 2010b; Scott & Dienes, 2010c; Topolinski & Strack, 2009; Tunney & Shanks, 2003; see also Dienes, 2004, 2008a for a review of subjective measures of awareness in implicit learning studies).

Dienes and Scott (2005) identify two types of knowledge used to guide string classification in AGL: structural knowledge and judgment knowledge. Structural knowledge refers to (conscious or unconscious) knowledge of the grammar acquired during the training phase. This may encompass aspects of the grammar such as whole items (represented as exemplars of the grammar), fragments of items (e.g.: permissible bigrams or trigrams), patterns of connection weights or other rules. Judgment knowledge is the (conscious or unconscious) knowledge constituted by such a judgment and leads a person to classify a string as grammatical or ungrammatical. That is, judgment knowledge is the knowledge that the string is grammatical or ungrammatical. When both types of knowledge are conscious, participants engage in conscious hypothesis testing of their held rules or use their conscious recollections of (parts of) exemplars encountered during training to guide their grammaticality judgments (e.g.: "I have (not) encountered ZTP before, therefore the string is (not) grammatical"). When structural knowledge is unconscious but the judgment of that knowledge is conscious, participants use feelings of intuition or familiarity to guide their judgments (e.g. "I know I'm correct but I don't know why") (Norman, Price, & Duff, 2006; Norman, Price, Duff, & Mentzoni, 2007). When both types of knowledge are unconscious, grammar decisions are mere guesses and no conscious preference for grammaticality is shown (i.e.: these decisions are made in the absence of metacognitive awareness). Structural knowledge attributions have shown themselves to be a useful tool to researchers investigating implicit learning and unconscious knowledge by discriminating between knowledge types in ways consistent with theory (e.g.: Chen et al., 2011; Dienes & Scott, 2005; Guo et al., 2011; Rebuschat & Williams, 2009; Scott & Dienes, 2008;

Scott & Dienes, 2010a; Scott & Dienes, 2010b; Scott & Dienes, 2010c; Wan, Dienes, & Fu, 2008; see Section 2.4 for the operational definitions of structural knowledge attributions used in the current experiment).

Reber (1976) found that asking people to find the rules in the strings during the training phase rather than just memorising the strings impaired later classification, indicating too much careful deliberation can be harmful. While later studies have often not detected a difference between rule search and memorisation conditions in AGL (see Berry & Dienes, 1993, p 57 for a review), Reber, Kassin, Lewis, & Cantor, 1980 argued the negative effect of rule search depended on grammar complexity (reminiscent of Dijksterhuis' claims about unconscious versus conscious thought; see also van den Bos & Poletiek, 2008, for a discussion of complexity measures in AGL). Reber's procedure involved contrasting what subjects are asked to do in the training phase; Dijksterhuis' procedure involves contrasting what subjects are asked to do after training and before testing. The latter has not yet been investigated with the AGL paradigm.

The AGL and standard UTT methodologies share parallels in that both involve complex information acquisition before forced choice decision making. In an AGL review paper, Pothos (2007) states that "implicit cognition may be well suited for processing complex stimuli" (p. 230). Essentially the grammaticality judgment in AGL tasks is akin to a complex decision making task. Sequence classification in AGL and decision making in UTT studies can be based on the application of memory and/or the weighting of salient attributes of test stimuli (thus, conscious hypothesis testing and unconscious familiarity processes; Scott & Dienes, 2008; Scott & Dienes, 2010b) which contribute to classification performance and both procedures are designed to tap into implicit processes by 'overloading' consciousness (or working memory). The fact that preference judgments (based on familiarity signals guiding choice) and memory processes operate during AGL and that both conscious and unconscious knowledge are demonstrably acquired during training makes it an ideal method to investigate deliberation without attention. Indeed, we may expect any beneficial effects of deliberation without attention (derived from a theory postulating a powerful unconscious) to have a greater effect on those decisions that are not based on conscious hypothesis testing. Dijksterhuis and Nordgren (2006) state that intuitive 'gut-feelings' without consciously knowing what those feelings are based on may well be due to the results of unconscious thought. They define intuition as "a feeling that something is right or wrong... while being largely unaware of where that feeling came from, or what it is based on". (p. 105). This is an important point and has not received much empirical attention (see however, Aczel et al., 2011; Ham & van den Bos, 2011). As discussed, the AGL literature has investigated these states of knowledge more extensively. In a recent study by Scott and Dienes (2010a), participants were trained on an artificial grammar presented either as letters or musical notes. At test, the modality of the grammar was switched (e.g.: the letter set was switched; the notes were transcribed to letters; or the notes were transcribed to novel symbols). It was found that decisions attributed to random selection yielded above chance accuracy whereas intuition, familiarity, rule or recollection based decisions were all at chance. One possible interpretation of this result is unconscious thought as decisions attributed to non-random strategies would have had a greater amount of conscious deliberation. That is, any beneficial effects of deliberation without attention may be revealed in those decisions involving the least amount of introspective awareness, i.e.: randomly selected (guess) responses.

In order to study the UTT phenomenon using the AGL paradigm, an intermediate phase was introduced between training and testing. Specifically, conditions were either immediate progression from training to testing, a 5 min period in which participants were instructed to think about the rules of training items just studied or a 5 min distraction period completing unrelated mathematics problems. A proviso of UTT is that the conscious is more suited to processing relatively simple information whereas the unconscious is suited to more complex materials. Thus grammar complexity measures were also introduced into the experimental design as it is currently unclear in the AGL literature how such measures affect metacognitive decision strategies (see Section 2.1). Using a well-investigated learning and decision making paradigm eliciting readily measurable conscious knowledge, intuitive, 'gut-feeling' unconscious knowledge and responses made in the absence of conscious awareness should clarify whether any beneficial effect of distraction in complex decision making compared to immediate testing facilitates processing of conscious or unconscious representations. Further, beneficial or harmful effects of post-training sustained conscious deliberation on conscious and unconscious representations could also be independently determined.

2. Method

2.1. Design

Two relatively simple grammars were used as controls for each other (S1 and S2), compared against two relatively complex grammars (C1 and C2). Grammars S1 and C1 were taken directly from van den Bos and Poletiek (2008) [originally referred to as grammars A and D, respectively]. S2 and C2 were adapted from their counterparts in order to generate unique strings (see Fig. 1). Complexity was based on topological entropy (TE) of the grammars (see Bollt & Jones, 2000 for a detailed explanation of calculating TE). Two levels of TE were used in this study in order to ensure participants would base grammaticality decisions on both conscious and unconscious structural knowledge. The lowest level (TE = 0.55) and a level in the top half (TE = 2.05) of the range previously used by van den Bos and Poletiek were selected to ensure an adequate range of complexity and above-chance classification accuracy (earlier pilot work using their most complex grammar (TE = 2.58) suggested participants' performance would be no better than chance). Activities between training and testing (the intermediate phase) were manipulated. Participants progressed straight from training to testing (immediate condition), were asked to think for

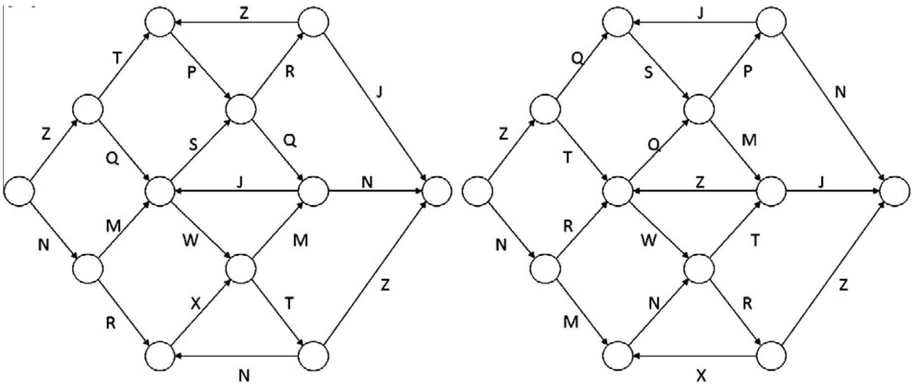

Fig. 1. (a) Grammar S1 (left) taken from Van den Bos and Poletiek (2008). Grammar S2 (right) adapted from S1. TE = 0.55. (b) Grammar C1 (left) taken from Van den Bos and Poletiek (2008). Grammar C2 (right) adapted from C1. TE = 2.05.

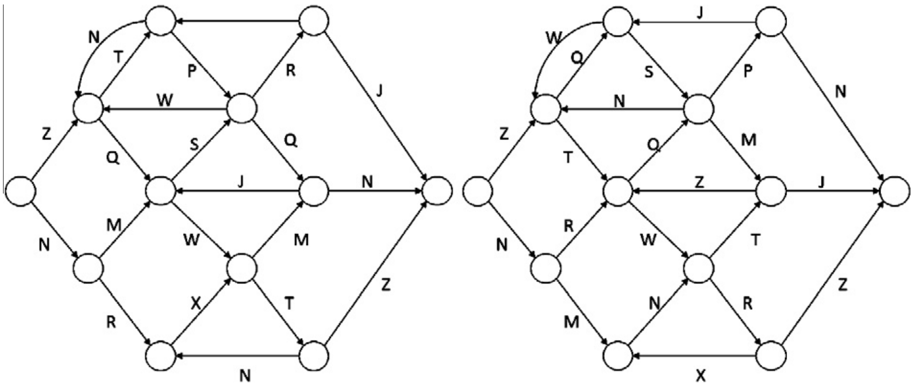

Fig. 1 (*continued*)

5 min about the rules governing the structure of the strings (rule discovery) or were asked to complete mathematical problems for 5 min (distraction).

2.2. Participants

150 participants were recruited at the University of Sussex (75% female) and were randomly assigned to one of the conditions: training and testing on either grammar S1, S2, C1 or C2 with one of three intermediate phases between testing and training (immediate, rule discovery or distraction; 50 participants per intermediate phase group). Ages ranged from 18 to 56 years (M = 22.90, SD = 5.07). Remuneration was either £3 or course credits.

2.3. Materials

Four grammars were used in the course of this experiment, two simple grammars (S1 and S2) and two complex grammars (C1 and C2) represented in Fig. 1.

60 strings from each grammar were generated, half of which were to be used in the training phase and half of which were to be used in the testing phase. String length was 5–11 characters. A 2×2 grammar cross-over design was used (see Dienes & Altmann, 1997). Grammatical strings for S1 were used as ungrammatical strings for S2 and vice-versa. The same was done for C1 and C2.

2.4. Procedure

E-Prime software was used to display the grammar strings and record responses. Participants were informed they were taking part in a learning and memory experiment as unconscious thought is purportedly goal-dependent (Bos et al., 2008). During training, they were instructed to look at the presented string on the monitor for 5 s. When the screen went blank they were required to write down as much as they could remember of the string before the next one appeared. After 30 strings the testing phase was over. All participants were then informed that there were rules governing how the strings were generated and they would be asked to classify further strings in terms of grammaticality. Those in the rule discovery condition were asked to think for 5 min about what these rules may be, focusing on how the strings began or finished or any pairs or triplets of letters or other parts of the strings that seemed important. They could type notes on the monitor during this time to aid conscious rumination (notes were unavailable to the participant after the five allotted minutes). A number of UTT studies have used anagrams as a distracter task, however this was considered too similar to the AGL task to be a suitable distracter in the current experiment. Instead, participants in the distraction condition completed an unrelated mathematics test for 5 min (similar to Dijksterhuis, 2004, who used a numerically based *n*-back distracter task). Participants in the immediate condition progressed straight from training to testing.

During the testing phase, participants viewed 60 further novel strings, 50% of which were grammatical. For the classification accuracy decision, participants indicated their choice by pushing the 1 (yes – the sequence is grammatical and conforms to the rules) or 0 key (no – the sequence is not grammatical and does not conform to the rules). Secondly they were asked to type their confidence in this response choosing any number between 50% and 100%. Finally, they were asked where they felt where their response arose from (knowledge attribution) adapted from one of the five options from Scott and Dienes (2008), corresponding to five numbers on the keyboard: random selection (1), intuition (3), familiarity (5), rules (7), recollection (9). It was made clear to participants that if they selected 50% confidence they should use the random selection attribution. The definitions of these categories were as follows: *Random Selection*: There is no basis for your response whatsoever. You may as well have flipped a coin (this response is based on 50% confidence); *Intuition*: You feel your response is correct but have no idea why; *Familiarity*: Your response is based on a feeling of something seen earlier, or a feeling that something has changed or is missing, but you have no idea what; *Rules*: You response is based on some rule(s) that you learned earlier and you could say what these rules are if asked; *Recollection*: Your response is based on the fact you either could or could not recollect seeing (parts of) the string in training. Once participants had given these responses for all 60 displayed strings, the experiment was over.

3. Results

3.1. Number of structural knowledge attributions

Responses based on rules or recollection were pooled into a conscious structural knowledge category (henceforth 'conscious structural knowledge'). Intuition and familiarity attributions were pooled into an unconscious structural knowledge category (henceforth 'feeling based'). Random selection responses (henceforth 'guesses') reflect instances where both structural and judgment knowledge are unconscious; as such they form their own category. The complexity factor was included to correspond to differing levels of complexity in standard UTT designs. However, no significant main effects of grammar complexity were found in any of the subsequent analyses, nor were there any significant interactions with this variable. Approximately equal numbers of all decision strategies were used as a function of complexity, suggesting both complexity levels resulted in adequate amounts of reported unconscious vs. conscious knowledge (the key assumption in UTT being conscious capacity is overloaded). This was taken as evidence that both levels of TE were sufficiently complex for unconscious processes to be revealed. Similarly, neither manipulated factor affected reported levels of confidence. For completeness, mean confidence in feeling based responses was 66% (SE = 0.6) and for conscious structural knowledge mean confidence was 76% (SE = 0.7). By definition guess responses were made with 50% confidence.

Table 1 shows the mean number of trials attributed to guesses, feelings or conscious structural knowledge. As trial attributions are not independent (e.g. using a 'rule' response entails not using an 'intuition' response), three separate one-way independent ANOVAs ($N = 150$) with intermediate phase (immediate progression vs. rule discovery vs. distraction) as the independent variable were conducted on the number of trials attributed to each knowledge type (out of 60 trials).

Table 1
Number of trials (out of sixty) attributed to each response type as a function of intermediate phase (standard errors appear in parentheses).

	Immediate	Rule discovery	Distraction
Guess	7.3 (0.8)	9.6 (1.5)	8.6 (1.3)
Feeling based	36.7 (1.7)	28.5 (1.7)	33.1 (1.9)
Conscious structural knowledge	16.0 (1.9)	21.3 (1.8)	18.3 (1.8)

Table 2
Percentage correct for each response type as a function of intermediate phase (standard errors appear in parentheses).

	Immediate	Rule discovery	Distraction
Guess	53.7 (2.9)	51.3 (2.8)	61.4 (3.2)
Feeling based	60.3 (1.3)	59.4 (2.0)	59.0 (1.6)
Conscious structural knowledge	66.9 (3.1)	69.7 (2.0)	66.7 (2.6)

For guess responses, there was no significant main effect of intermediate phase, $F(2, 147) = 0.81$, $p = .445$, $\eta_p^2 = .01$. For feeling-based responses, there was a significant main effect of intermediate phase; $F(2, 147) = 5.41$, $p = .005$, $\eta_p^2 = .07$. LSD post hoc tests revealed the following pattern: Rule where linked items (by wavy underline or by crossing) are non-significantly different. Finally, for conscious structural knowledge responses, there was no significant main effect of intermediate phase, $F(2, 147) = 2.15$, $p = .120$, $\eta_p^2 = .03$. Taken together, there was evidence that after rule discovery participants were less likely to attribute knowledge to feelings than immediate subjects, but otherwise we did not detect differences in the proportion of different attribution types.

3.2. Intermediate phase and classification accuracy

Table 2 shows the percentage of correct responses for guesses, feelings or conscious structural knowledge. Three separate one-way independent ANOVAs (immediate progression vs. rule discovery vs. distraction) were conducted on the percentage of correct responses according to knowledge attribution. Firstly, the hypothesis that any beneficial effect of distraction would be reflected in decisions made without conscious meta-knowledge was addressed. Note the degrees of freedom and group sizes throughout: not all participants used the three knowledge attribution categories during testing, hence do not have accuracy data for those attributions (a value of 0 indicating the category was not used is permissible when assessing the distribution of knowledge types per intermediate phase; this is not so when assessing the accuracy of those categories hence those cells are empty for these analyses). Therefore separate one-way independent ANOVAs were ran on each attribution type to maximise statistical power. We acknowledge this may inflate the family-wise error rate hence a Bayesian analysis is also presented to address specific hypotheses derived from UTT.

The one-way ANOVA on guess responses ($n = 130$) was significant (see Fig. 2), $F(2, 127) = 3.09$, $p = .049$, $\eta_p^2 = .05$. In line with the UTT predictions, subsequent *t*-tests revealed distraction to result in significantly higher accuracy than rule discovery, $t(84) = 2.39$, $p = .010$ (one-tailed), Cohen's $d = 0.51$, and immediate progression, $t(85) = 1.77$, $p = .040$ (one-tailed), Cohen's $d = 0.38$. The difference between immediate progression and rule-discovery was not significant, $t(85) = 0.60$, $p = .554$ (two-tailed), 95% CI [−.06, .11], Cohen's $d = 0.13$. Furthermore, distraction resulted in accuracy significantly above the chance value of 50%, $t(42) = 3.63$, $p = .001$ (two-tailed), Cohen's $d = 0.78$, satisfying the guessing criterion of unconscious knowledge (Dienes et al., 1995). This was not true of immediate progression, $t(43) = 1.26$, $p = .214$ (two-tailed), Cohen's $d = 0.30$, nor rule discovery, $t(42) = 0.46$, $p = .646$ (two-tailed), Cohen's $d = 0.01$. (Note though that in Fig. 2, the 95% confidence intervals of each group are consistent with reasonable guessing knowledge, so we are not asserting the null hypothesis for any group.)

In terms of feeling based responses ($n = 148$), no significant main effect was found, $F(2, 129.3) = 0.16$, $p = .857$, $\eta_p^2 = .00$ (with Brown–Forsythe correction). Similarly, for conscious structural knowledge responses ($n = 139$), there was no significant main effect of intermediate phase, $F(2, 136) = 0.42$, $p = .656$, $\eta_p^2 = .01$. Thus, there was no evidence of a beneficial effect of distraction on responses made with the availability of some degree of conscious judgment knowledge, consistent with a large body of knowledge failing to find such effects (Acker, 2008).

Next we sought to establish the strength of evidence for UTT for each of guess, feelings and conscious structural knowledge. While the tests were non-significant in the latter two cases, it is not clear whether this counts as evidence against the application of UTT to conscious knowledge or whether the evidence is just insensitive (Dienes, 2011).

Bayes factors indicate continuous degrees of support for hypotheses. Values of over 3 can be regarded as substantial evidence for the experimental hypothesis (here, that a period of distraction would improve the quality of decisions relative to immediate progression). Values less than 1/3 can be considered substantial evidence for the null hypothesis. Values around 1 indicate no substantial evidence either way and suggest the experimental design does not have sufficient sensitivity (values

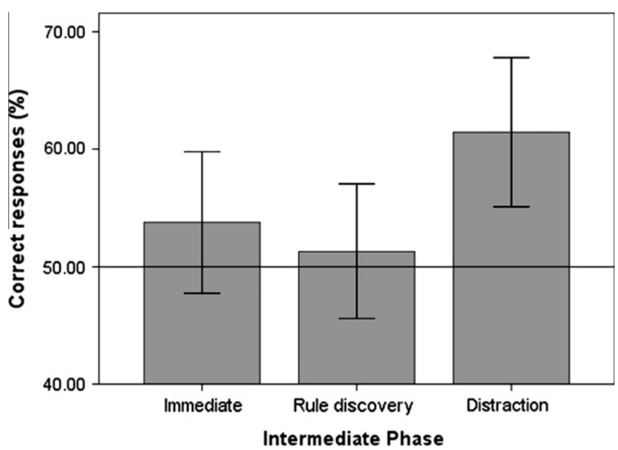

Fig. 2. The percentage of correct guess responses as a function of intermediate phase. The error bars represent 95% confidence intervals. The horizontal line represents chance performance.

suggested by Jeffreys, 1961; see also Dienes, 2011). These values should not be corrected for multiple comparisons. In order to calculate Bayes factors, the plausible range of effect sizes consistent with the theory need to be specified. Differences between groups in AGL are unlikely to ever exceed 15%, given that 65% is a typical performance level for any one group (for review, see e.g.: Dienes, 2011). Furthermore, the grammars used in the current experiment were based on those used by van den Bos and Poletiek (2008) who found roughly 65% accuracy for their grammar with the lowest TE and performance generally declined as TE increased (values roughly replicated in the current experiment). Thus, the distraction manipulation might produce any advantage over immediate testing between 0% and 15% but it is highly unlikely to produce a value greater than that. The predictions of UTT were modelled as a uniform between 0% and 15%, with an advantage for distraction over immediate but not vice versa.

For guessing, the mean difference between the distraction and immediate groups was 7.7 (SE of the difference = 4.3), and hence $B = 3.28$, indicating substantial evidence for the UTT hypothesis in the case of guesses. For feelings, the mean difference between the distraction and immediate groups was -1.3 (SE of the difference = 2.1), and hence $B = 0.11$, indicating substantial evidence for the null and against the UTT hypothesis in the case of feelings. For conscious structural knowledge, the mean difference between the distraction and immediate groups was -0.2 (SE of the difference = 4.1), and hence $B = 0.33$, indicating substantial evidence for the null hypothesis in the case of conscious structural knowledge.

(See Dienes (2008b, 2011) for discussions on the differences between Bayesian and Orthodox statistics and their relative advantages and disadvantages. See also the associated website, http://www.lifesci.sussex.ac.uk/home/Zoltan_Dienes/inference/Bayes.htm, for further discussion and an on-line Bayes factor calculator. See also Newell and Rakow (2011) for another Bayesian analysis of UTT effects.)

4. Discussion

The aim of the study was to investigate unconscious thought – or incubation – effects in an implicit learning paradigm. We found that participants who were distracted between training and testing showed higher accuracy in their guess responses than those who attempted to discover grammar rules or immediately progressed from training to testing. Furthermore, only distracted participants satisfied the guessing criterion of unconscious knowledge (Dienes et al., 1995). The intermediate phase manipulation had no detectible effect on the accuracy of responses accompanied by conscious judgments of having relevant structural knowledge. Consistently, the intermediate phase did not detectibly influence the confidence levels associated with feeling based or conscious structural knowledge responses, that is when meta-knowledge was conscious (it is expected that conscious and unconscious structural knowledge response are associated with differing confidence levels but the manipulation did not affect confidence within these response types). This suggests that in the case of the learning of statistical regularities, such as in AGL, deliberation without attention is beneficial to those decisions made in the absence of meta-cognitive awareness. Presumably this effect reflects unconscious organisation of information, for example the decay of fast weights (Cleeremans, 1993). The results here suggest distraction facilitated the processing of *unconscious* representations. No differences in accuracy between intermediate phase groups were found when judgment knowledge was conscious. This finding is appealing: we may expect the effects of a manipulation based on a theory positing a 'powerful unconscious' to be reflected in responses made without conscious awareness.

Furthermore, the results support the notion that the quality of decision making after distraction is different from those made immediately, in contrast to the findings of Waroquier et al. (2010, experiment 1). Waroquier et al. concluded that the most parsimonious account of UTT findings is that distracted participants form an impression on-line and no deliberation without attention occurs (see also Lassiter et al., 2009). Our findings challenge this conclusion but only for decisions made without awareness of knowing. This contradiction is likely due to methodological differences. Information acquisition in typical UTT studies involves forming an impression of a relatively small number of different apartments, cars or other everyday objects; in the current study, participants would have become more familiar with their respective grammar structure over the course of information acquisition. Furthermore, many UTT studies have involved a single choice whereas here the test consisted of sixty trials (which also accounts for the possibility of on-line impression formation as all participants were exposed to novel strings at test and would not be able to form an impression of those strings until exposure; see also Strick et al., 2011). Additionally, this study was conducted with the phenomenal state of the participant in mind (cf Aczel et al., 2011). No benefit of distraction was found when participants reported their decision strategy was based on a consciously recognised memory (rules, recollection), or even when they were consciously aware of applying a meta-cognitive feeling to decision making without awareness of the direct source of that feeling (intuition, familiarity).

As stated, distraction did not improve grammaticality decisions made with conscious judgement knowledge, which may contradict previous UTT findings. When participants report their decision strategy as holistic or based on a few pieces of information (Dijksterhuis, 2004), clearly they are conscious of that. This contrasts with guessing where participants are unaware of knowing anything relevant to the task. Dijksterhuis and Nordgren (2006) state that it is "necessary to shed more light on how unconscious thought works and how the unconscious transfers its information to consciousness" (p. 107). In the current study, any beneficial effect of deliberation without attention did not transfer to conscious awareness. Thus, one explanation for previous null results in UTT studies could be that the results of 'unconscious thought' did not, in fact, present themselves to consciousness Experimental designs without sensitivity to the phenomenological state of the participant could overlook such an effect. Aczel et al. (2011) did account for the conscious status of the knowledge used by participants in a housemate rating task. They used a scale from 0 (pure intuition/guess) to 10 (pure memory), however no differences were found between the distraction, immediate and rumination groups. This may be a similar effect as seen in the current study: there was little change between the immediate and distraction groups in terms of reported decision strategy, but the *quality* of guess responses was improved after distraction relative to both other groups. However, Aczel et al. found a positive correlation between their rating scale and preference for choosing the 'correct' housemate within their unconscious thought group (i.e.: those who reported a stronger reliance on memory), which is the opposite pattern that is predicted made by UTT (see, however, Ham & van den Bos,, 2011 for a demonstration of unconscious thought in both implicit and explicit decision making).. Using an alternative methodology (as suggested by Acker, 2008) which elicits measurable amounts of unconscious knowledge likely aided in finding effects in the direction predicted by UTT. Recently, a new methodology designed to detect the presence of unconscious knowledge has been introduced into the AGL literature: namely no-loss gambling (Dienes & Seth, 2010; Mealor & Dienes, 2012). In the test phase of a no-loss gambling AGL study, participants attribute the basis of their grammaticality judgment by either endorsing that judgment (in order to gain a reward if their judgment is correct) or by betting on a transparently random process. If participants choose to bet on the process, there is a 50% chance they will gain a reward and in doing this, no conscious preference for grammaticality is shown. As this method clearly separates conscious from unconscious judgment knowledge, it may be useful to researchers wishing to investigate deliberation without attention with respect to the conscious status of the participants' meta-knowledge. It is unclear if the manipulations and measurements currently used are sensitive enough to pick out responses based on guesses. Furthermore, these results may have implications for implicit learning studies more broadly insofar as the introduction of an interval between training and testing can result in measurable behavioural differences in accuracy.

Importantly, there are other possible interpretations of the results presented here. When there is conscious judgment knowledge, self-paced conscious thought may lead to the best decisions (Payne et al., 2009), i.e. less conscious thought than demanded by conscious reflection conditions in typical UTT experiments. Any advantage of distraction relative to immediate decisions in typical UTT studies could be due to a small though finite opportunity for conscious thought in the distraction condition. This interpretation of apparent 'deliberation without attention' effects does not presuppose ongoing unconscious processing of stimuli after they have been presented, merely that too much rumination can detract from decision making quality (Wilson & Schooler, 1991). In the current study, the possibility that a period of self-paced conscious thought between training and testing may improve decision making in AGL cannot be ruled out (relative to an arbitrarily enforced period of conscious rumination). However, this theory does not explain a benefit only for guesses. Indeed, these are cases where participants may not know what to think about at all. But the "optimally small amount of conscious thought" rather than "unconscious thought" hypothesis should be more thoroughly investigated in future studies, and cannot be ruled out by current data (see also the integration of conscious and unconscious thought; Nordgren et al., 2011).

Newell and Rakow (2011) recently conducted a Bayesian analysis on 16 studies closely following the methodology of the standard UTT experimental approach. They concluded there was substantial evidence in favour of the null hypothesis that there is no difference between conscious and unconscious thought in complex decision making about ethical dilemmas (contrast the meta-analysis of Strick et al., 2011, for other paradigms). The Bayesian analysis presented here focused on finding evidence of a positive effect of distraction over immediate decision making according to the self-reported decision strategy of the participant. Our results open the possibility that UTT may well apply especially when knowledge is involved that can be identified as unconscious by subjective measures.

We present some evidence of the benefits of deliberation without attention in a well established paradigm (AGL), with a clear objective scale by which to measure the quality of decision making. There was no effect of 'unconscious thought' acting on decisions made with conscious judgment (either feeling-based or when structural knowledge is available to consciousness), however there was evidence of a benefit acting on guess responses. Others have suggested that the advantages of 'unconscious thought' are likely to be modest (e.g.: Acker, 2008; Aczel et al., 2011). The results presented in the current study, with a large sample size, indeed show a modest (roughly an 8% advantage over immediate progression and 10% over rule discovery), but statistically significant, benefit acting on less than 15% of all responses given by participants (self-reported random selection responses). Future research should focus on the circumstances under which the results of deliberation without attention present themselves to consciousness and the associated processes (see Scott & Dienes, 2008; Scott & Dienes, 2010d, for discussions of how knowledge may become conscious in AGL).

References

Acker, F. (2008). New findings on unconscious versus conscious thought in decision making: Additional empirical data and meta-analysis. *Judgment and Decision Making, 3*, 292–303.

Aczel, B., Lukacs, B., Komlos, J., & Aitken, M. R. F. (2011). Unconscious intuition or conscious analysis? Critical questions for the deliberation-without-attention paradigm. *Judgment and Decision Making, 6*, 351–358.

Berry, D. C., & Dienes, Z. (1993). Implicit learning: Theoretical and empirical issues. Hove, UK: Erlbaum.

Bollt, E. M., & Jones, M. A. (2000). The complexity of artificial grammars. *Nonlinear Dynamics, Psychology, and Life Sciences, 4*, 153–168.

Bos, M. W., Dijksterhuis, A., & van Baaren, R. B. (2008). On the goal-dependency of unconscious thought. *Journal of Experimental Social Psychology, 44*, 1114–1120.

Bos, M. W., Dijksterhuis, Ap., & van Baaren, R. B. (2011). The benefits of "sleeping on things": Unconscious thought leads to automatic weighting. *Journal of Consumer Psychology, 21*, 4–8.

Calvillo, D. P., & Penaloza, A. (2009). Are complex decisions better left to the unconscious? Furher failed replications of the deliberation-without-attention effect. *Judgment and Decision Making, 4*, 509–517.

Chen, W., Guo, X., Tang, J., Zhu, L., Yang, Z., & Dienes, Z. (2011). Unconscious structural knowledge of form-meaning connections. *Consciousness and Cognition, 20*, 1751–1760.

Cleeremans, A. (1993). *Connectionist models of sequence learning*. Cambridge: MIT Press.

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

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

Dienes, Z. (2008b). *Understanding psychology as a science. An introduction to scientific and statistical inference*. Hampshire, England: Palgrave Macmillan.

Dienes, Z. (2011). Bayesian versus orthodox statistics: Which side are you on? *Perspectives on Psychological Science, 6*, 274–290.

Dienes, Z. (2012). Conscious versus unconscious learning of structure. In P. Rebuschat & J. Williams (Eds.), *Statistical learning and language acquisition*. Mouton de Gruyter Publishers.

Dienes, Z., & Altmann, G. (1997). Transfer of implicit knowledge across domains? How implicit and how abstract? In D. Berry (Ed.), *How implicit is implicit learning?* (pp 107–123). Oxford: 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*, 1322–1338.

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

Dienes, Z., & Seth, A. (2010). Gambling on the unconscious: A comparison of wagering and confidence ratings as measures of awareness in an artificial grammar task. *Consciousness and Cognition, 19*, 674–681.

Dijksterhuis, A. (2004). Think different: The merits of unconscious thought in preference development and decision making. *Journal of Personality and Social Psychology, 87*, 586–598.

Dijksterhuis, A., Bos, M. W., Nordgren, L. F., & van Baaren, R. B. (2006). On making the right choice. The deliberation-without-attention effect. *Science, 311*, 1005–1007.

Dijksterhuis, A., & Nordgren, L. F. (2006). A theory of unconscious thought. *Perspectives on Psychological Science, 1*, 95–109.

Dijksterhuis, A., & van Olden, Z. (2006). On the benefits of thinking unconsciously: Unconscious thought can increase post-choice satisfaction. *Journal of Experimental Social Psychology, 42*, 627–631.

Evans, J. B. T. (2008). Dual processing accounts of reasoning, judgment, and social cognition. *Annual Review of Psychology, 59*, 255–278.

Evans, J. B. T. (2010). Intuition and reasoning: A dual-process perspective. *Psychological Inquiry, 21*, 313–326.

Glöckner, A., & Witteman, C. (2010). Beyond dual-process models: A categorisation of processes underlying intuitive judgment and decision making. *Thinking and Reasoning, 16*, 1–25.

Gonzalez-Vallejo, C., Lassiter, G. D., Bellezza, F. S., & Lindberg, M. J. (2008). "Save angels perhaps": A critical examination of unconscious thought theory and the deliberation-without-attention effect. *Review of General Psychology, 12*, 282–296.

Guo, X., Zheng, L., Zhu, L., Yang, Z., Chen, C., Zhang, L., et al (2011). Acquisition of conscious and unconscious semantic prosody. *Consciousness and Cognition, 20*, 417–425.

Ham, J., & van den Bos, K. (2010). On unconscious morality: The effects of unconscious thinking on moral decision making. *Social Cognition, 28*, 74–83.

Ham, J., & van den Bos, K. (2011). On unconscious and conscious thought and the accuracy of implicit and explicit judgments. *Social Cognition, 29*, 648–667.

Ham, J., van den Bos, K., & van Doorn, E. A. (2009). Lady Justice thinks unconsciously: Unconscious thought can lead to more accurate justice judgments. *Social Cognition, 27*, 509–521.

Handley, I. M., & Runnion, B. M. (2011). Evidence that unconscious thinking influences persuasion based on argument quality. *Social Cognition, 29*, 668–682.

Jeffreys, H. (1961). *The theory of probability* (3rd ed.). Oxford University Press.

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

Lassiter, G. D., Lindberg, M. J., Gonzalez-Vallejo, C., Bellezza, F. S., & Phillips, N. D. (2009). The deliberation-without-attention effect: Evidence for an artifactual interpretation. *Psychological Science, 20*, 671–675.

Lerouge, D. (2009). Evaluating the benefits of distraction on product evaluations: The mind set effect. *Journal of Consumer Research, 36*, 367–379.

Mealor, A., & Dienes, Z. (2012). No-loss gambling shows the speed of the unconscious. *Consciousness and Cognition, 21*, 228–237.

Newell, B. R., & Rakow, T. (2011). Revising beliefs about the merit of unconscious thought: Evidence in favour of the null hypothesis? *Social Cognition, 29*, 711–726.

Newell, B. R., Wong, K. Y., Cheung, J. C. H., & Rakow, T. (2009). Think, blink or sleep on it? The impact of modes of thought on complex decision making. *The Quarterly Journal of Experimental Psychology, 62*, 707–732.

Nordgren, L. F., Bos, M. W., & Dijksterhuis, A. (2011). The best of both worlds: Integrating conscious and unconscious thought best solves complex decisions. *Journal of Experimental Social Psychology, 47*, 509–511.

Norman, E., Price, M. C., & Duff, S. C. (2006). Fringe consciousness in sequence learning: the influence of individual differences. *Consciousness and Cognition, 15*, 723–760.

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.

Payne, J. W., Samper, A., Bettman, J. R., & Luce, M. F. (2009). Boundary conditions on unconscious thought in complex decision making. *Psychological Science, 19*, 1118–1123.

Persaud, N., McLeod, P., & Cowey, A. (2007). Post-decision wagering objectively measures awareness. *Nature Neuroscience, 10*, 257–261.

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

Queen, T. L., & Hess, T. M. (2010). Age differences in the effects of conscious and unconscious thought in decision making. *Psychology and Aging, 25*, 251–261.

Reber, A. S. (1967). Implicit learning of artificial grammars. *Journal of Verbal Learning and Verbal Behaviour, 6*, 317–327.

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

Reber, A. S. (1976). Implicit learning of synthetic languages: The role of the instructional set. *Journal of Experimental Psychology: Human Learning and Memory, 2*, 88–94.

Reber, A. S., & Allen, R. (1978). Analogic and abstraction strategies in synthetic grammar learning: A functionalist interpretation. *Cognition, 6*, 189–221.

Reber, A. S., Kassin, S. M., Lewis, S., & Cantor, G. (1980). On the relationship between implicit and explicit modes in the learning of a complex rule structure. *Journal of Experimental Psychology: Human Learning and Memory, 6*, 492–502.

Rebuschat, P., & Williams, J. (2009). Implicit learning of word order. In N. A. Taatgen & H. Van Rijn (Eds.), *Proceedings of the 31st annual conference of the cognitive science society*. Austin, TX: Cognitive Science Society.

Scott, R. B., & Dienes, Z. (2008). The conscious, the unconscious, and familiarity. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 34*, 1264–1288.

Scott, R. B., & Dienes, Z. (2010a). Knowledge applied to new domains: The unconscious succeeds where the conscious fails. *Consciousness and Cognition, 19*, 391–398.

Scott, R. B., & Dienes, Z. (2010b). Fluency does not express implicit knowledge of artificial grammars. *Cognition, 114*, 372–388.

Scott, R. B., & Dienes, Z. (2010c). Prior familiarity with components enhances unconscious learning of relations. *Consciousness and Cognition, 19*, 413–418.

Scott, R. B., & Dienes, Z. (2010d). The metacognitive role of familiarity in artificial grammar learning: Transitions from unconscious to conscious knowledge. In A. Efklides & P. Misailidi (Eds.), *Trends and Prospects in Metacognition Research*. Springer.

Strick, M., Dijksterhuis, A., Bos, M. W., van Sjoerdsma, A., & Baaren, R. B. (2011). A meta-analysis on unconscious thought effects. *Social Cognition, 29*, 738–762.

Strick, M., Dijksterhuis, A., & van Baaren, R. B. (2010). Unconscious thought effects take place off-line, not on-line. *Psychological Science, 21*, 484–488.

Thorsteinson, T. J., & Withrow, S. (2009). Does unconscious thought outperform conscious thought on complex decisions? A further examination. *Judgment and Decision Making, 4*, 235–247.

Topolinski, S., & Strack, F. (2009). The architecture of intuition: Fluency and affect determine intuitive judgments of semantic and visual coherence and judgments of grammaticality in artificial grammar learning. *Journal of Experimental Psychology: General, 138*, 36–63.

Tunney, R. J., & Shanks, D. R. (2003). Subjective measures of awareness and implicit cognition. *Memory and Cognition, 31*, 1060–1071.

Usher, M., Russo, Z., Weyers, M., Brauner, R., & Zakay, D. (2011). The impact of the mode of thought in complex decisions: Intuitive decisions are better. *Frontiers in Psychology, 2*, 1–13.

Van den Bos, E., & Poletiek, F. H. (2008). Effects of grammar complexity on artificial grammar learning. *Memory and Cognition, 36*, 1122–1131.

Wan, L., Dienes, Z., & Fu, X. (2008). Intentional control based on familiarity in artificial grammar learning. *Consciousness and Cognition, 17*, 1209–1218.

Waroquier, L., Marchiori, D., Klein, O., & Cleeremans, A. (2009). Methodological pitfalls of the Unconscious Thought paradigm. *Judgment and Decision Making, 7*, 601–610.

Waroquier, L., Marchiori, D., Klein, O., & Cleeremans, A. (2010). Is it better to think unconsciously or to trust your first impression? A reassessment of Unconscious Thought Theory. *Social Psychological and Personality Science, 1*, 111–118.

Wilson, T. D., & Schooler, J. W. (1991). Thinking too much: Introspection can reduce the quality of preferences and decisions. *Attitudes and Social Cognition, 60*, 181–192.