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Conscious and Unconscious: Passing Judgment

By

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Thesis submitted for the degree of Doctor of Philosophy

School of Psychology

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Declaration

I hereby declare that this thesis has not been and will not be, submitted in whole or in part to
another University for the award of any other degree

Andy D. Mealor

28/09/2012

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Preface

This thesis is written in the European/US format, consisting of a collection of studies as manuscripts submitted for publication. The studies are preceded by an overview chapter consisting of a general introduction to the relevant literature and how the empirical work relates to the outlined themes, ending with a brief summary of each study. The conclusions chapter integrates the findings and relates them back to the literature. Each empirical chapter can also be considered as a standalone piece of work. At the time of writing, data from Chapters II, III and V have been published in the international peer-reviewed journal *Consciousness and Cognition*, co-authored by myself and Zoltan Dienes.

Mealor, A. D., & Dienes (2013). The speed of metacognition: Taking time to get to know one's structural knowledge. *Consciousness and Cognition*, 22, 123-136.

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

Mealor, A. D., & Dienes, Z. (2012). Conscious and unconscious thought in artificial grammar learning. *Consciousness and Cognition*, 21, 865-874.

Data from Chapters IV and VI have been submitted for publication. The empirical chapters in this thesis closely resemble their submitted counterparts. The analyses in the empirical chapters use orthodox methods, which are supplemented with standardised effect sizes and Bayes factors where appropriate.

Andy D. Mealor

28/09/2012 (updated 08/05/2013)

Summary

The extent to which conscious and unconscious mental processes contribute to our experiences of learning and the subsequent knowledge has been subject to great debate. Dual process theories of implicit learning and recognition memory bear many resemblances, but there are also important differences. This thesis uses subjective measures of awareness to explore these themes using the artificial grammar learning (AGL) and remember/know (R/K) procedures.

Firstly, the relationship between response times associated with intuition and familiarity based responding (conscious judgment of unconscious structural knowledge) compared to rule and recollection based responding (conscious structural knowledge) in AGL were found to be strikingly similar to remembering and knowing; their R/K analogues. However, guessing (unconscious judgment knowledge) was also distinct from intuition and familiarity based responding. Secondly, implicit learning in AGL was shown to occur at test, which would not be expected in R/K. Finally, wider theories of cognition, unconscious thought and verbal overshadowing, were shown to have measurable effects on AGL and R/K respectively. The approach used in this thesis shows the merits of both in-depth analysis within a given method combined with the synthesis of seemingly disparate theories.

This thesis has built upon the important distinction between conscious and unconscious structural knowledge but also suggests the conscious-unconscious division for judgment knowledge may be as important. Implicit learning and recognition memory tasks differ in the kinds of mental processes that subjective measures are sensitive toward; particularly so in situations where judgment knowledge is unconscious. Different theories and methods divide nature in different ways; the conscious-unconscious judgment distinction may prove an important one.

Chapter I

Introduction: Dual processes in implicit learning and recognition memory

“There is no doubt that explicit and implicit measures are tapping different qualities of memory”

(Roediger, Rajaram & Geraci, 2007, p. 253).

“Recognition is at the heart of intuitive expertise” (Hogarth, 2010, p. 341)

The ways in which we learn about our environments and experience knowledge is closely linked with distinctions between conscious and unconscious mental processes. From stimulus-bound feelings of familiarity to higher-order hypothetical reasoning, debate continues regarding the extent to which such processes are conscious or unconscious and the degree to which resultant phenomenological experiences are or are not qualitatively different and separable. There is a rich history in psychology of positing dual processes that underlie many aspects of human cognition including reasoning (Evans, 2003, 2008, 2010), judgment and decision making (Dijksterhuis & Aarts, 2010; Dijksterhuis & Nordgren, 2006; Glöckner & Witteman, 2010), and social cognition (Bargh & Morsella, 2008; Winkielman & Schooler, 2011). This thesis focuses on dual processes in learning and memory with a particular spotlight on two commonly used methodologies used in these areas, namely the artificial grammar learning paradigm (AGL; Reber, 1967) and the remember/know paradigm (R/K; Tulving, 1985). Despite some equivocation between particular positions, the central theme motivating the use of these methods is the assertion of two systems fundamental to performance in these cognitive domains: one automatic, high capacity and largely unconscious; and one controlled, limited capacity and conscious. Where the boundary is drawn between what can be considered a “conscious” or “unconscious” system or process, or indeed that the key distinction between such processes should rely on their conscious status, is certainly yet to be established (Reder, Park & Kieffaber,

2009) but the notion of multiple (interactive) mechanisms has nonetheless proved a useful taxonomy to researchers examining learning and memory. Both the AGL and R/K methodologies have been used extensively to investigate dual processes and, despite tapping into seemingly quite separate areas of cognition, this chapter highlights both the similarities and differences between the theoretical implications related to these paradigms, and discusses broader theories of knowledge acquisition, development and expression; empirical demonstrations of which lend themselves more readily to one paradigm over the other.

Subjective measures of awareness in learning and memory

Researchers interested in the phenomenological experiences associated with the expression of learning and memory processes demand rigorous measures of conscious awareness. Objective measures of awareness typically deal with how much someone knows through being able to discriminate between states of the world. When people show sufficient performance in their ability to make reliable judgments on a given task, the conclusion that follows is there was conscious knowledge guiding that judgment (e.g. Dienes, 2004, 2008a; Dienes & Seth, 2010a). Yet, such a conclusion discounts the mental state that led to that behaviour, thus potentially overlooks the extent to which people know consciously, as opposed to simply know. Thus, objective measures are often insufficiently sensitive to individuals' mental states for researchers interested in decision processes and not simply the decision itself. Subjective measures, on the other hand, index the degree to which someone is aware of their knowledge and these methods do allow researchers to investigate the basis of decisions which is fundamental in allowing estimations of how different processes contribute to performance (see Dienes, 2008a for review and the philosophical basis behind subjective measures). These measures are thus useful in measuring distinctions between conscious and unconscious knowledge as delineated by dual process theories, based on the assumption that knowledge is conscious if it subjectively seems to people that they are aware of their state of knowing. However, this distinction is not as simple

as it may seem: it is possible for people to be consciously aware of knowing but be largely unaware of where that feeling came from. The AGL and R/K experimental protocols elicit these experiences and the measurement techniques used in these studies attempt to capture the underlying processes.

Dual processes and the Artificial Grammar Learning paradigm

AGL is the method used by Reber (1967) when he originally defined “implicit learning”. This type of learning is characterised as an incidental process (indeed, one may be unaware of learning anything at all) which results in knowledge largely blocked from introspection, i.e. is unconscious. This learning process is the counterpart to explicit learning which requires top-down conscious reflective strategies and results in knowledge which is open to report (e.g. Reber, 1989). In a typical AGL study, participants are exposed to a number of sequences generated from a rule-based structure (the ‘grammar’) without knowing those sequences obey a set of strictly defined rules (see Figure 1 for an example). During this training phase, they may be asked to memorise, write down or simply look at those sequences, which to them appear to look more or less randomly ordered (e.g.: XMTRRM could be generated from the schematic depicted in Figure 1).

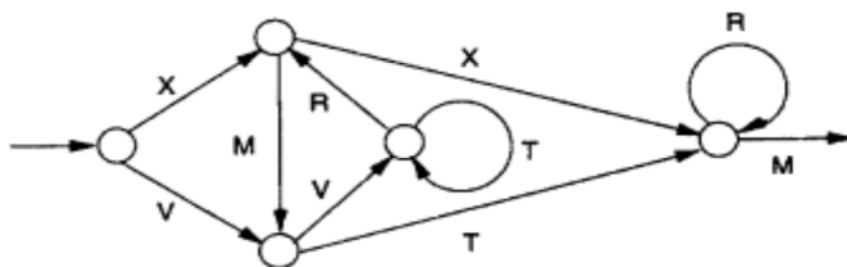


Figure 1: An example of an artificial grammar. Sequences are generated by beginning at the input node on the left and adding letters by following the arrows until the output node on the right is reached.

After exposure to the training sequences, participants are informed of the existence of rules which underlie the structure of the stimuli without being told what those rules are. Then during the test phase they are required to discriminate between novel grammatical sequences which obey the studied rules and ungrammatical sequences which violate those rules. A robust finding is that people classify at above chance levels: 65% accuracy is typical where 50% reflects baseline performance. Reber (1967, 1969) initially suggested that much of the knowledge acquired during AGL is unconscious as participants are able to reliably discern grammatical and ungrammatical sequences yet show great difficulty in detailing any relevant studied rules at the end of the experiment through free report. However, the seeming inability of participants to verbalise grammar rules does not, in and of itself, indicate unconscious knowledge. For instance, useful rules could have been forgotten or knowledge could be withheld if the participant has little confidence in their decision strategy or thinks their knowledge is not of interest to the experimenter, for example if they classified on the basis of similarity to a remembered exemplar but thinks the experimenter wants to hear about hypothesised rules (Berry & Dienes, 1993; Dienes, 2008a). Subsequently, different methods of measuring conscious awareness of knowledge have been introduced into the AGL literature such as continuous numerical confidence estimates (e.g.: Dienes, Altmann, Kwan & Goode, 1995); binary verbal confidence estimates (e.g.: “guess” vs. “sure”; Tunney & Shanks, 2003); and methods of wagering to indicate levels of confidence (Persaud, McLeod & Cowey, 2007; Dienes & Seth, 2010b). These methods plausibly eliminate potential free report bias as participants are not asked the exact method used to determine the grammaticality of the sequence but instead measure confidence levels in the subjectively defined decision strategy. Furthermore, such judgments can easily be reported for each grammaticality decision to minimise any effect of forgetting. Dienes et al. (1995) codified two criteria by which knowledge in AGL can be considered unconscious. Firstly, the *guessing criterion* is satisfied when above baseline accuracy is shown but the participant believes they are guessing. Secondly, the *zero-correlation criterion* is met when there is an absence of a relationship between accuracy and confidence (see Dienes, 2004, for the assumptions behind these subjective measures of

awareness). Thus, subjective confidence can itself become the variable of interest. Within an AGL study, the guessing criterion can reveal unconscious knowledge and the zero-correlation criterion can reveal some relationship between confidence and accuracy, thus these criteria demonstrate the acquisition of both unconscious and conscious knowledge of grammar structure (Dienes et al., 1995). However, confidence reports deal with the metacognitive experience of the acquired knowledge; that is how confident one is in their grammaticality decision. Such methods do not allow inference of the status of the knowledge that led to that level of confidence, i.e.: awareness of the parts of a given sequence that make it grammatical or ungrammatical. To this end, structural knowledge attributions have been introduced into the AGL literature to determine levels of conscious awareness of what contributes to the grammaticality decision (Dienes & Scott, 2005).

At least two types of knowledge are used to guide sequence classification in AGL: structural knowledge and judgment knowledge. Structural knowledge refers to the (conscious or unconscious) knowledge of the grammar structure acquired during training which can consist of, for example, salient bigrams or trigrams, patterns of connection weights, training examples represented as examples of the grammar, repetition structure or other (correlated) rules (see e.g.: Pothos, 2007, 2010; van den Bos & Poletiek, 2008, for discussions on grammar features learned in AGL). Judgment knowledge refers to the metacognitive experience of having some such relevant structural knowledge which leads one to classify a sequence as grammatical or ungrammatical and again can be conscious or unconscious (it is this form of knowledge captured by confidence ratings). When structural knowledge is conscious, the judgment knowledge that accompanies it is also typically conscious. In this case, people classify AGL sequences according to hypothesised rules or on the basis that they recollect or do not recollect (parts of) the current test stimulus from what was encountered during training, e.g.: “I (don’t) remember seeing XRV earlier; therefore the sequence is (not) grammatical”. The

When structural knowledge is unconscious, the accompanying judgment knowledge can be conscious or unconscious. In the former case, participants classify the sequences on the basis

of experienced intuition or familiarity, e.g.: “I know my judgment is correct but I don’t know why”; “There is something (un)familiar about this sequence but I don’t know what”. See, for example, Mangan (1993, 2003) and Norman, Price and Duff (2006), for discussions on ‘fringe feelings’ of rightness and wrongness. When both structural and judgment knowledge are unconscious the phenomenology is that of guessing, and no conscious preference for grammaticality is shown (see Figure 2 for the relationship between structural and judgment knowledge and the reported phenomenology). Note that it may be feasible that one consciously knows a rule but is unaware of using it on a given trial. Under the Dienes and Scott (2005) framework, this may be considered unconscious judgment knowledge of conscious structural knowledge. The introduction of structural knowledge attributions was motivated by a version of Higher Order Thought theory (e.g. Rosenthal, 2000), where one must have a thought about a mental state to make that mental state conscious. Structural knowledge becomes conscious when one has a relevant thought about having specifically that knowledge, but otherwise remains unconscious.

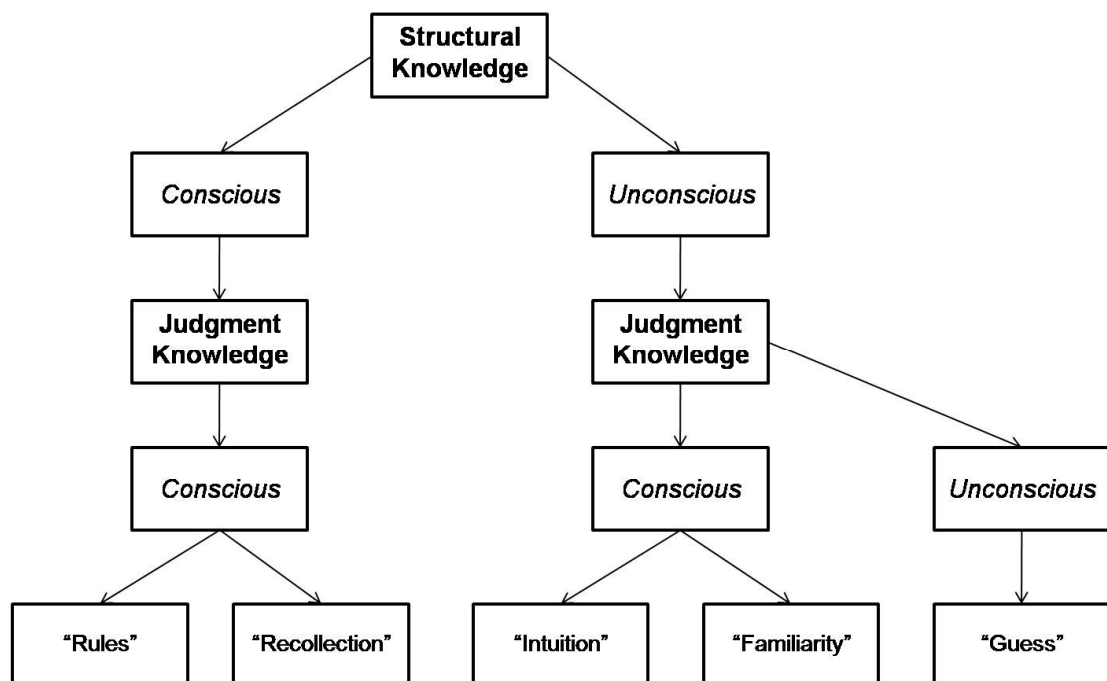


Figure 2: The relationship between the conscious status of structural and judgment knowledge. The bottom row represents self-reported structural knowledge attributions (Dienes & Scott, 2005; Scott & Dienes, 2008).

Such knowledge attributions reflect different forms of metacognitive commitment that a test sequence obeys or disobeys the studied structure, and theoretically can be dissociated from confidence levels. It may seem tautological to state that conscious awareness of the structure that leads to conscious judgment obligates higher confidence than conscious judgment lacking the introspective awareness that led to a judgment (and indeed conscious structural knowledge attributions do often yield higher confidence estimates than unconscious structural knowledge attributions; Dienes & Scott, 2005; Scott and Dienes, 2008), however this is not necessarily the case. For example, it is perfectly possible for one to have relatively high confidence in a feeling of intuition or familiarity where this sense compels a feeling of previously encountering the information. Conversely, it is possible to have relatively low levels of confidence in a weakly-held memory or overly-complex consciously derived hypotheses (Dienes, Scott & Seth, 2010). As such, structural knowledge attributions have good face validity and, where relevant, should be reported alongside confidence ratings.

Scott and Dienes (2008, 2010a) present a dual-process model of AGL which states there are two methods by which knowledge is acquired during AGL based on the distinction between incidental and deliberate learning. Incidental learning is said to have occurred when knowledge is acquired but there was no intention to learn the materials and such passive exposure results in lower-order familiarity (unconscious structural knowledge) approximately reflecting the frequency of encountered grammatical features. Alternatively, participants can be instructed to search for rules during training, in which case deliberate learning based on hypothesis-testing occurs. Incidental learners derive conscious judgment knowledge at least in part through a process of familiarity calibration where further exposure to novel sequences allows for ever more fine-grained estimates of the mean familiarity of all sequences encountered thus far. Early in the test phase, only those sequences on the extremities of subjective familiarity give rise to confidence when structural knowledge is unconscious. Sequences with familiarity above the subjectively derived mean are endorsed as grammatical; those with familiarity below this mean are rejected as ungrammatical. As the mean estimate of familiarity becomes more reliable, it

becomes clear that estimates of confidence stem from difference between the familiarity estimate of the current sequence and the mean familiarity of sequences encountered thus far, giving rise to conscious judgment knowledge. Over the course of testing, familiarity estimates are updated through exposure to further sequences which allows for conscious structural knowledge to develop. For example, the realisation may be made that sequences containing a certain element had never been classified as grammatical; this realisation then informs subsequent grammaticality decisions.

Deliberate learners display greater amounts of conscious structural knowledge earlier in the test phase through attempting to decipher grammar rules during training. However, deliberate and incidental learning do not necessarily operate in isolation and there may be interactions between the two. Conscious structural knowledge attributions encapsulate rule and recollection based responding, which are functionally similar. Surmising a salient element can only occur in a certain point in the sequence to deem that sequence grammatical (a rule) entails consciously remembering that element. It should be noted that the recollection attribution may not always reflect deep structural knowledge (of, for example, connection weights, repetition structure etc.) but may simply reflect conscious recognition that a salient element remembered from is present or absent in the current test sequence. This need not be structured. Nonetheless, this still fulfils the criteria of conscious knowledge in the sense that one is aware of what has given rise to the final classification judgment. The key notion here is the conscious or unconscious knowledge which feeds into judgment knowledge.

The theoretical motivation for structural knowledge attributions gives them good face validity; yet this does not make for a good measurement method without empirical verification. Indeed, it has been shown that rule search instructions do increase the availability of conscious structural knowledge over memorisation instructions and the addition of a secondary divided attention task— competing for attentional resources – decreased its accuracy but not that of unconscious structural knowledge (Dienes & Scott, 2005). That is, structural knowledge attributions seem to do their job through capturing a relevant distinction in nature.

Dual processes and the Remember/Know paradigm

In a highly influential paper, Tulving (1985) considers the concepts of anoetic, noetic and autonoetic consciousness and their relation to the conscious status of memory retrieval. Briefly, anoetic refers to a state of non-knowing; noetic to knowing; and autonoetic to self-knowing. These distinctions led to the development of the R/K paradigm which has been used extensively in the study of recognition memory. In a typical R/K study, participants are shown lists of to-be-remembered stimuli (often word lists). After training, they are required to discriminate between previously presented targets and new lures. If a participant believes the test stimulus was presented earlier then an 'old' judgment is made; if not then a 'new' decision is made. Participants also give the basis of this judgement, which reflect different forms of metacognitive experience that an item had been presented earlier. R responses are given if they *remember* seeing the item from training (e.g.: with source information such as spatial or temporal detail, presentation modality or contextual information such as what they were thinking of when they previously saw that item); or a K response if they do not consciously recollect seeing the stimulus from training but 'just *know*' (or are sure) that it was presented earlier without access to the richer detail associated with remembering. The R/K method sometimes employs a third option, G, for *guess* responses where the participant could not decide whether or not the item was previously presented but guessed that it was. R responses are thought to index a recollection process; that is consciously controlled, effortful and relatively time consuming memory retrieval. K responses, on the other hand, are thought to index familiarity which is conceptualised as a process which is not under conscious control and is relatively effortless and automatic.

Recent interpretations of R/K data are based on signal-detection models. Subjective memory strength of an item presented at test corresponds to the weight of evidence that the item had occurred in the previous learning phase and drives the participant to categorize the item as 'old' or 'new'. When memory strength is not great enough to result in recognition, a 'new' response is given. With sufficient strength to reach a certain threshold, an R response is given

indicating recollection. When the strength falls between these two criteria, a K response is given indicating the items has given rise to a feeling of familiarity but without conscious recollection (some models also posit that a G response is given when the memory strength falls close to the old/new criterion meaning the participant cannot decide whether that item is old or new). Some researchers value this single process signal detection framework as a parsimonious account of R/K data (e.g.: Donaldson, 1996; Dunn, 2004). However, R/K studies have provided evidence of dissociations between such remember and know judgments, which are problematic for unidimensional models of recognition but are easily accommodated by dual process models. For example, deeper processing increases remembering but not knowing (Gardiner, 1988) and divided attention at encoding affects remembering more than overall recognition (Jacoby, Woloshyn & Kelley, 1989). See Diana, Reder, Arndt and Park (2006); Yonelinas (2002); Yonelinas, Aly, Wang & Koen (2010) for detailed reviews. Furthermore, Jacoby (1991) considers familiarity to be an automatic process and shows it can influence behaviour beyond conscious control through the process dissociation procedure (e.g.: acquired familiarity is automatically expressed when participants are instructed to inhibit responses which are made nonetheless), and the Yonelinas (1994) dual-process signal detection model views recollection as an all-or-nothing process that either succeeds or fails compared to familiarity which corresponds to a signal detection process. Such evidence *prima facie* supports a dual process account of recognition (contrast Dunn, 2004). One particular example that is difficult to reconcile with single process theories is Mandler's (1980) classic "butcher on the bus" anecdote. This case refers to the experience of seeing someone one is aware of knowing and such a strong feeling of familiarity induces a memory search in order to identify the source of that feeling. Such a search may or may not result in successful recollection ("That's the butcher!"). This example demonstrates instances where a strong feeling of familiarity with high confidence feels, subjectively, qualitatively different from remembering. Thus, Wixted & Mickes (2010) present a continuous dual process (CDP) model of recognition. This model posits old/new decisions and associated confidence ratings are driven by aggregated memory strength in a bidimensional manner insofar as the recollection and familiarity processes are separate, continuous axes (thus,

it is not assumed that R judgments are based on a binary process, although may appear so in experimental settings) which can account for high confidence K responses and instances where the confidence of R and K responses overlap (see also Higham, Perfect and Bruno, 2009, for accuracy monitoring and its relation to confidence in recognition).

Comparison of AGL and R/K findings

The AGL and R/K paradigms have been used extensively to investigate learning and memory phenomena and the conscious status of the resultant knowledge. Specifically, both methods involve the application of conscious and unconscious memory processes in order to make judgments regarding the ‘oldness’ of stimuli (in a concrete sense in R/K; in an abstract, structural sense in AGL). Both methods conceptualise familiarity as a continuous stimulus-bound output such that the familiarity of a test item is compared to what is stored in the memory system and, with some stipulations, recollection processes as symbolic events involving information that extends beyond the familiarity signals generated by the stimulus. Furthermore, both methods are amenable to interpretation according to a signal detection theory framework. Classification judgments in AGL and recognition judgments in R/K require successful worldly discrimination between targets (grammatical sequences or old words) and lures (ungrammatical sequences or new words). Grammaticality judgments and old/new decisions are driven by a comparison between the current to-be-classified stimulus and what is stored in the memory system. The probability distributions relating to grammaticality or oldness are placed on an axis representing low to high memory strength or familiarity. Discrimination behaviour is driven by where the current item falls on this axis; items eliciting greater strength have a greater weight of evidence of being grammatical or old. However, there is uncertainty in this process and the distributions overlap. Successful discrimination is shown as the difference in standardised memory strength of these distributions increases and a criterion is placed indicating the strength at which a ‘grammatical’ or ‘old’ decision is made. Ungrammatical or new items exceeding this

criterion result in a false alarm (i.e.: erroneous endorsement); grammatical or old sequences exceeding this criterion result in a hit (correct endorsement). An increasingly conservative criterion reduces both hits and false alarms and an increasingly liberal criterion decreases hits and false alarms. Signal detection offers a bias free estimate of discrimination ability and can independently assess response bias, compared to simply assessing the proportion of correct responses (compare a hypothetical scenario of three participants, where 50% of test stimuli correspond to earlier learning. One rejects all stimuli, one endorses all stimuli and another responds randomly. All would attain the same proportion of correct responses and show no reliable discrimination but two have extreme response biases). For thoroughness, the proportion of correct responses and signal detection measures will be used throughout this thesis (signal detection, in and of itself, is silent on the subject of measures of awareness; Seth, Dienes, Cleeremans, Overgaard & Pessoa, 2008). Where appropriate, the proportion of correct responses and signal detection measures are separated according to self-reported measures of awareness (see Higham, 2007; Higham et al. 2009, for type-two signal detection and metacognitive monitoring of accuracy).

Neither the AGL nor R/K paradigm can be said to be process pure in that only implicit or explicit strategies are invoked (e.g.: Jacoby, 1991) but this potential criticism can be considered a virtue when investigating the processes in combination, given appropriate hypotheses and sufficiently sensitive measurement tools. Parsimonious accounts of human learning and memory processes require ample explanatory power in a given domain, yet need to be general enough to apply beyond simply one methodology. Due to the number of similarities between proposed processes underlying AGL and R/K performance, it should be quite possible to derive predictions from theories instantiated in one paradigm that apply to the other. However, there are certain differences between them, and other related theories of cognition from which reasonable predictions can be derived that lend themselves more to one paradigm than the other. Shared processes and caveats relevant to this thesis are now discussed.

Decision making processes

One obvious difference between AGL and R/K is the basis upon which decisions are made at test. AGL relies on classifying a novel stimulus in terms of similarity to previous exemplars whereas responses in R/K are dependent on an exact match between the current test stimulus and memory contents. Is this distinction important? Many recognition memory researchers subscribe to the view that R and K responses reflect qualitatively different forms of metacognitive experiences about a current test item having been previously presented. Similarly, recollection and familiarity in AGL reflect different metacognitive experiences that the current test sequence conforms to or violates the grammar structure studied in training. R responses in R/K and conscious structural knowledge responses in AGL are consequents of consciously remembering (or not in the case AGL, but see type two signal detection as applied to recognition in Higham et al., 2009) salient aspects of the stimulus, and reflect some episodic awareness of a previous learning encounter. K responses in R/K are given when there is a feeling of ‘oldness’ that the item has been presented previously without consciously recollecting its occurrence and in AGL, responses based on the conscious judgment of unconscious structural knowledge are given when some aspect(s) of the test sequence result in a feeling of grammaticality (akin to ‘oldness’) or ungrammaticality (‘newness’) but without consciously identifying those aspects that led to that feeling. Thus, in both cases there is conscious judgment knowledge for familiarity (K) responses. Tunney (2007) used R/K/G instructions in an AGL task and found a reliable contribution of both recollection and familiarity when test items were either old grammatical items (presented again from training), new grammatical items (as is typical in AGL studies) and even on a grammar transfer task, showing through self-report that processes as captured by R/K methods do contribute to sequence classification in AGL (see also Tunney, 2010). Structural knowledge attributions reveal an analogous pattern of a combination of familiarity and recollection processes in AGL (Dienes & Scott, 2005; Scott & Dienes, 2008; see also Higham, 1997; Higham & Vokey, 2000; Higham, Vokey & Pritchard, 2000; Lotz & Kinder, 2006, for comparisons of controlled and automatic influences in AGL). Self-report

measures thus reveal similar processes underlying performance in these methodologies, and there is much theoretical overlap between the two.

Response times of knowledge types

Response times (RT) provide a useful proxy measure to investigate different memory processes. As dual process theories conceptualise familiarity as a rapid, automatic process compared to the more effortful and controlled (hence, inherently time consuming) recollection process, the time taken to make judgments based on these respective processes should differ. There is much evidence in the recognition memory literature to support this claim. Speeded tests have shown that above baseline recognition is available faster than source information (thought to require recollection). To take one example, Boldini, Russo and Avons (2004) manipulated modality matches and level of processing, finding, at short response deadlines, higher discrimination for modality matches which disappeared at longer deadlines whereas an increase in accuracy for deeply processed stimuli emerged only at longer deadlines (see also Feredoes & Postle, 2002; Gronlund & Ratcliffe, 1989; Hintzman & Caulton, 1997; McElree, Dolan & Jacoby, 1999; Yonelinas & Jacoby, 1996).

Response times associated with different mental processes in AGL have not been studied as extensively as those in recognition. Nevertheless, the published research parallels findings from the recognition memory literature. For example, Higham et al. (2000) found that familiarity with to-be-rejected sequences was elicited under time pressure which could be inhibited with sufficient processing time. Furthermore, Turner and Fischler (1993) found that response deadlines decreased the accuracy of classification decisions following rule search training instructions which is thought to maximise explicit learning of the grammar to a greater extent than incidental learning (see also Johansson, 2009). However, there is also evidence not entirely consistent with a rapid familiarity process. In self-paced R/K tests, R judgments are made more rapidly than K responses and G responses (indicating guessing) are made most

slowly (e.g.: Dewhurst, Hitch & Barry, 1998; Dewhurst, Holmes, Brandt & Dean, 2006; Duarte, Henson & Graham, 2008; Henson, Rugg, Shallice, Josephs & Dolan, 1999; Konstantinou & Gardner, 2005; Wheeler & Buckner, 2004; see also Sheldon & Moscovitch, 2010). Yonelinas (2002) considers this finding an artefact of experimental instructions as participants are instructed to give a K response if the item is *not* recollected (i.e.: a K response is only given once the recollection process has failed, lengthening the RT of K responses). However, Dewhurst et al. (2006) decoupled the old/new decision from the R/K/G decision. Participants were re-presented with items they had classified as ‘old’ and the effect of decision type remained: items that were subsequently classified as ‘remembered’ had been identified more rapidly than those classified as ‘known’ followed by ‘guessed’. The interpretation of Dewhurst et al. is not to discount a rapid familiarity response (in-line with speeded recognition tasks) but when extra time is available it is utilised to make subjectively optimal decisions based on the information a familiarity signal affords to metaknowledge, possibly in order to evaluate the familiarity of a test item to training items when additional contextual information is not available (see also Dewhurst & Conway, 1994; Knott & Dewhurst, 2007).

The faster RTs of R responses may reflect the greater ease of processing when contextual information is available and such processes can occur rapidly (see also the two stage recollection hypothesis of Moscovitch, 2008 and Sheldon & Moscovitch 2010). Thus, in self-paced tests the ‘natural’ RTs of different response types appears to be inversely related to levels of conscious awareness from recollective experience to knowing to guessing but familiarity-based responding can be elicited rapidly when externally enforced. Note also that confidence is inversely related to RT (Petrusic & Baranski, 2003, 2009) and recollection tends to be associated with higher confidence than familiarity or guessing. The interpretation of the relationships between confidence, RT, and self-reported knowledge types has been matter of great debate (e.g. Dewhurst et al., 2006; Ratcliff & Starns, 2009; Rotello, Macmillan & Reder, 2004; Rotello & Zeng, 2008). Nonetheless, it would be of theoretical interest to establish

whether these findings extend to subjective experience in AGL, which in turn may prove useful in disentangling such processes. This will be investigated in Chapters II and III.

Differences between knowledge types and experience acquired in the paradigms

This chapter has thus far dealt primarily with the similarities between familiarity and recollection processes underlying performance in AGL and R/K. However, there may also be important divergences between the different types of knowledge gained in the course of these experiments. When structural knowledge is conscious in AGL, recollection can guide classification (“I remember XRV from training”), or hypothesised (semantic) rules can be used. Conscious states of awareness are indicated by R responses in R/K designs (“I remember item Y being presented between item X and item Z”) Thus, both conscious structural knowledge responses and R responses indicate conscious awareness of the determinants of the judgment (there is a greater emphasis on episodic influences in R judgments, but surmising a rule to guide classifications in AGL typically will depend on a previous encounter with the elements that constitute that rule; see Whittlesea & Dorken, 1993, for an episodic account of implicit learning).

The conscious judgment of unconscious structural knowledge in AGL is revealed when one is not consciously aware of the determinants that led to the feeling of familiarity. For example, knowledge that VX is an allowable bigram is not conscious knowledge until one specifically represents it as knowledge (Dienes, 2012), whereas subjectively knowing an item in R/K was previously presented does entail some episodic knowledge of its earlier presentation, thus K responses indicate at least some awareness of what gave rise to that feeling (“I know the item was presented earlier although I do not recall its occurrence”) without introspective source access to what led to that feeling. Although these familiarity processes are conceptually similar and likely related (as delineated thus far in this chapter), the antecedents of such feelings elicited in the two paradigms differ which may prove an important difference. K responses are not

unconscious in and of themselves as this mental content, and its determinants, can be reported, i.e.: the K response is dependent on recognition of a salient item and instructions in R/K emphasise K responses should be given when an item is not recollected yet the participant is sure of an item's previous occurrence (Roediger, Rajaram & Geraci, 2007). However, this is not necessarily the case when it comes to unconscious structural knowledge in AGL, where attributions stress the importance of not knowing where the feeling of intuition or familiarity stems from (these attributions emphasise confidence in the judgment but also non-knowing of its precursors). Furthermore, familiarity ratings in AGL predict classifications in AGL even when no conscious metaknowledge is reported (Scott & Dienes, 2008), which has not been demonstrated in recognition (the issue of guessing is returned to later in this chapter). Thus, unconscious structural knowledge resulting from implicit learning may be dependent on the materials being rule-based or otherwise complex and not obvious to the learner (Reber & Allen, 1978).

The learning of word lists common to R/K cannot reasonably be said to be implicit in the sense that one is unaware of learning anything. The types of conscious and unconscious knowledge acquired in the paradigms may therefore be sensitive to different manipulations. Numerous studies have codified what is learned in AGL including recurring chunks or fragments of sequences (Dulany, Carlson & Dewey, 1984; Knowlton & Squire, 1994; Perruchet & Pacteau, 1990), patterns of repetitions (Brooks & Vokey, 1991; Vokey & Higham, 2005), symmetries (Jiang et al., 2012) as well as knowledge of whole exemplars (Vokey & Brooks, 1992; see also van den Bos & Poletiek, 2008 and Pothos, 2007, for review). Furthermore, the influence of recognition in AGL is greater when sequences are re-presented at test, compared to novel grammatical test sequences (Lotz & Kinder, 2006). On the other hand, successful performance in R/K tasks is solely dependent on the whole structure of a test item and its match with memory. Debate continues regarding what exactly the memory strength variable represents from mnemonic information, "evidence" or quantitative versus qualitative differences in the degrees of source information (see Wixted & Mickes, 2010 for review).

According to Whittlesea and colleagues, the sources of performance in AGL and R/K studies (i.e. classifications and recognition) can be based on common underlying principles of processing fluency (e.g.: Whittlesea and Leboe, 2000, 2003), with more fluent processing of materials resulting in a greater feeling of familiarity. Although manipulations designed to increase fluency in recognition studies have shown increases in recognition (e.g. Dewhurst & Anderson, 1999; Jacoby & Whitehouse, 1989; Rajaram, 1996; Rajaram & Geraci, 2000; Whittlesea, 1993), its contribution to accurate performance in AGL has recently been questioned. Scott and Dienes (2010b) manipulated perceptual fluency in AGL using a sequence classification task. They found that perceptual fluency did influence responding, but in a manner unrelated to grammaticality, thus was not a source of accuracy in AGL (see also Buchner, 1994; Kinder, Shanks, Cock & Tunney, 2003).

In sum, the processes driving recognition judgments and grammaticality judgments share many similarities but there are also important differences and dual process distinctions remain useful points of reference. The remainder of this chapter will discuss manipulations more suited to investigate the type of knowledge gained in one paradigm over the other.

Familiarity decay, learning at test and feedback

Yonelinas (2002) states that familiarity associated with recognition decays rapidly in the intermediate term compared to recollection (Hockley, 1992; Yonelinas & Levy, 2002). This is in comparison to the longer term, where reports of both remembering and familiarity diminish (Gardiner & Java, 1991; Tunney, 2010). In AGL, above chance performance is also retained, but is reduced, over the long term (Allen & Reber, 1980; Tunney & Bezzina, 2007). However, one of the hallmarks of the results of implicit learning is its robustness (e.g. Reber, 1992). Many tasks requiring expertise are thought to depend upon implicit systems from procedural motor skills such as catching a thrown ball (e.g. Reed, McLeod & Dienes, 2010) through to conceptual

tasks such as medical diagnosis (Cleeremans, 2006), learning which requires procedural experience of the task and not purely following externally given explicit rules.

AGL is often used as a simplified analogy for natural language learning (Gomez & Gerken, 2000; Kovic, Westermann & Plunkett, 2008; Neil & Higham, in press; Rebuschat & Williams, 2009; Robinson, 2010), much of which is based on exemplar based learning as opposed to didactic teaching of grammar (Matthews, 1997). When speaking your native language, you are making use of your structural knowledge and this knowledge is not necessarily open to conscious awareness. For instance, it is difficult to explain to a second language learner why your version of their statement would be better. This is an example of when judgment is conscious but the nature of the structure (language rules) which led to that judgment is not (Dienes, 2012). However, feedback is consistently given when using language by virtue of being understood and responded to by others, which is not the case in many laboratory-based implicit learning studies. If much of the responding in AGL is based on familiarity, and similar processes underlie AGL performance and language acquisition (compare Chomsky, 1957; although the content of the sentence “Colourless green ideas sleep furiously” is completely unfamiliar, its structure conforms to common syntax, i.e. global familiarity can be theoretically dissociated from grammaticality and grammaticality classifications. In the context of AGL, participants are likely to infer grammaticality from subjective familiarity but this is not the sole source of judgments; e.g.: Scott & Dienes, 2008, show that grammaticality predicts classifications beyond subjective familiarity for conscious structural knowledge and Scott & Dienes 2010b show grammaticality predicts classifications in a grammar transfer task beyond familiarity when judgment knowledge is unconscious) it then follows that feedback should improve or at least maintain that familiarity in a laboratory setting and this hypothesis is yet to be tested with respect to the conscious status of underlying structural knowledge. Conversely, feedback would not be expected to impact on recognition as measured by R/K methods as this method is concerned with matching an exact test item match with memory contents as opposed to using familiarity signals to make classifications based on structured regularities.

Feedback could allow for greater reliance on a familiarity trace that has been externally verified as valid when that trace is based on the inter-relations between elements in a grammar sequence; it is unlikely that feedback would achieve the same result when familiarity is based on matching memory to a whole single item. Note exemplar models often model recognition as matching the test item to all items in memory at once, e.g. Hintzman's (1984) MINERVA 2 model, so in this sense recognition and AGL are not different (Dienes, 1992). On this model, a direct match of a test item to one item in memory happens to strongly influence the sum over all items, as the sum is a non-linear function of similarity, but the fact is that the comparison is always over all items in the model (see also Jamieson & Mewhort, 2009). Assuming feedback supports the use of a familiarity trace, it may then serve to increase familiarity with lures that share semantic relations with targets (given a suitable number of presentations), as cues activate memory traces and the model applies to generic memory processes (cf. Ardnt & Hirshman, 1998). Interestingly, however, feedback has been shown to reduce levels of false memories in recognition tasks specifically designed to elicit false memories (Fazio & Marsh, 2010; McConnell & Hunt, 2007), making it unclear how feedback would influence R/K judgments. Further highlighting the difference between methodological approaches is the issue of counterbalancing. Word lists in R/K tend to be matched on word frequency. In AGL, grammar cross-over designs are often used where ungrammatical test sequences obey a different set of regularities from those encountered during training (Dienes & Altmann, 1997). This opens the possibility that participants implicitly learn this second set of regularities at test and this knowledge may be expressed through familiarity as the test phase progresses (by definition, they need not be aware of this learning); the R/K method does not allow for a second (implicit) learning opportunity at test. Note this does not discount the possibility that familiarity processes underlying performance on the two tasks are similar, just that the R/K method would be insensitive to detecting such an effect upon familiarity. This issue is addressed in Chapter IV.

Rule-based learning versus item recognition: unconscious thought and verbal overshadowing

To extend the discussion of the preceding paragraph, other theories of cognition lend themselves more readily to AGL or R/K. Two will be considered in this thesis: unconscious thought theory (UTT; Dijksterhuis, 2004; Dijksterhuis & Nordgren, 2006) and verbal overshadowing (VO; Schooler, 2002; Schooler & Engstler-Schooler, 1990). UTT postulates a powerful unconscious that is far less constrained in its processing ability than capacity-limited conscious thought. Evidence for this theory comes from decision making tasks where participants are provided with information describing different decision options, for example apartments or cars. Each alternative is associated with a different proportion of positive and negative attributes. After information acquisition, participants are instructed to think about the options for a few minutes ('conscious thought') or are distracted with an irrelevant task such as solving anagrams ('unconscious thought') for the same amount of time and occasionally an immediate decision making condition is included. Unconscious thinkers tend to pick the option with the most desirable attributes more often than conscious thinkers, or immediate deciders, when a large amount of information has to be evaluated (e.g.: Bos, Dijksterhuis & van Baaren, 2008; Dijksterhuis, 2004; Ham & van Den Bos, 2010, 2011; Strick, Dijksterhuis, Bos, Sjoerdsma & van Baaren, 2011; contrast however, Acker, 2008; Aczel, Lukacs, Komlos & Aitken, 2011; Waroquier, Marchiori, Klein & Cleeremans, 2010.)

UTT relates to AGL as unconscious thought is said to be particularly suited to follow rules and weights salient aspects of stimuli in a naturalistic manner (the "deliberation without attention" hypothesis). Artificial grammars are rule based structures in which certain elements appear more frequently than others, and grammatical test items share more elements with training items than ungrammatical items. It is reasonable to posit decisions attributed to non-random strategies receive more task-relevant (stimulus bound) conscious deliberation than random strategies, and too much conscious deliberation can lead to inferior decision making (Wilson & Schooler, 1991; Waroquier et al., 2011). However, UTT remains controversial. The effect is found when the to-be-encoded information is sufficiently complex to overload

conscious capacity, but the standard paradigm has not convincingly demonstrated the influence of unconscious knowledge. That the AGL paradigm demonstrably elicits both conscious and unconscious knowledge through self-report makes it an ideal procedure to investigate UTT predictions. The stimuli used in studies showing an unconscious thought effect must have various attributes for them to be weighted in an appropriate manner. As such, a standard recognition task (as opposed to, for example, a decision making, impression formation or problem solving task) would be unlikely to reveal any beneficial effect of unconscious thought, when performance is measured through exact item matches and there are no rules or attributes to weight. Therefore, the R/K method may not be sensitive enough to find the small effects traditionally associated with unconscious thought (Acker, 2008). However, unconscious thought shares similarities with another theory which has been widely investigated with respect to recognition memory phenomena, namely verbal overshadowing.

VO is said to occur when the engagement of verbal processes is deleterious to performance on a given task, perhaps in a similar manner to how rigorous conscious thought can sometimes be detrimental to performance on complex tasks (Dijksterhuis, 2004; Wilson & Schooler, 1991). For example, Schooler and Engstler-Schooler (1990) asked participants to watch a videotape of a salient individual. Some of those participants subsequently described the face while others did not. Describers performed more poorly than non-describers suggesting recognition was impaired. Although many VO recognition studies have been conducted (see Chin & Schooler, 2008; Meissner, Sporer & Susa, 2008; Schooler, 2002, for reviews), surprisingly few have used R/K methods to determine if subjective experiences of knowledge are affected by verbalisation in different ways (see, however, Lloyd-Jones & Brown, 2008). The theory of VO does not invoke the rule-principle of UTT (in that the unconscious naturally weights the importance of aspects of the decision), rather it suggests that verbal processing, particularly of non-verbal stimuli, leads to deficiencies in recognition through the verbal memory dominating (overshadowing) the visual. The effect may stem from interference caused by recoding a visual stimulus verbally (Schooler & Engstler-Schooler, 1990); a general transfer

toward local processing at the expense of globally processing an entire stimulus (inappropriate processing; Schooler, 2002); a conservative shift in recognition (Clare & Lewandowsky, 2004), or some combination of these factors depending on the task at hand (Chin & Schooler, 2008; Lloyd-Jones, Brandimonte & Bäuml, 2008). To summarise, the implicit learning of an artificial grammar would be more likely to elicit an unconscious thought effect through unconscious deliberation of the rule-based nature of the stimuli; and recognition a VO effect through the dominance of the verbal over visual memory trace. Unconscious thought theory is applied to an AGL task in Chapter V and verbal overshadowing is invoked in an R/K task in Chapter VI.

Guessing

Thus far, this chapter has dealt primarily with responses accompanied by conscious metaknowledge, either based on remembering something task relevant or using familiarity signals which result in a feeling of knowing to guide classification behaviour. But what about cases where conscious metaknowledge is not available? Guess responses occur in AGL when both structural and judgment knowledge are unconscious. According to the Scott and Dienes (2010a) single process framework of unconscious structural knowledge, guess responses indicate instances where the familiarity of the current test item falls close to the subjective mean familiarity of all sequences encountered thus far (confidence, hence a feeling of intuition or familiarity is expressed as sequences decrease in proximity to this mean) and responses based on this phenomenology often yield above baseline accuracy, satisfying the guessing criterion of unconscious knowledge (e.g.: Dienes et al., 1995; Dienes & Altmann, 1997; Dienes & Scott, 2005; Dienes & Seth, 2010b; Scott & Dienes, 2008, 2010c; Tunney & Shanks, 2003). However, this is not the case in many R/K/G studies where G responses do not result in reliable discrimination between targets and lures. The Wixted and Mickes (2010) CDP model posits G responses are given when memory strength for an item falls close to the old/new criterion. Gardiner, Ramponi and Richardson-Klavehn (2002) conducted a meta-analysis of G responses

in R/K/G designs, finding that G responses are most dependent on the strictness or leniency of response criteria. As response criterion becomes more lenient, the accuracy of G responses falls from above to below baseline discrimination between targets and lures. They note that this may just reflect natural variability, although there may be some as yet undiscovered variable or condition which systematically results in above chance guessing. Thus, the state of the art is that AGL is the more sensitive tool to isolate accurate guess responses.

Scott and Dienes (2008, 2010a) find that familiarity ratings predict grammaticality judgments in AGL even when participants make guess responses, showing that participants are not always aware of using familiarity to guide their responses. Gardiner, Ramponi and Richardson-Klavehn (1998) discuss transcripts of R/K/G experiences, concluding that through self-reports, guess decisions can express feelings of familiarity but also contain irrelevant strategies and inferences which were not directly related to memories of studied items (i.e.: contaminated with task irrelevant familiarity). This is perhaps due to the type of stimuli used in R/K designs. The majority of such studies are conducted using word lists which participants are liable to have pre-experimental familiarity with and so it is perhaps not surprising that G responses are tainted by non-experimental associations likely through recent encounters with the target word or its semantic correlates. Similarly, stimuli in recognition studies are processed at the global level. This is averted in AGL by virtue of learning novel stimuli based on statistical contingencies which can be evaluated by various means. Furthermore, AGL studies have employed numerous measurement methods to investigate responses made without a metacognitive experience of knowing. In everyday language, people may have their own idiosyncratic definition of 'guess' which can encompass a range of feelings related to making estimations without sufficient information to do so with certainty. As such, guessing can potentially mean 'low confidence' and if a person has at least some confidence in a decision or representation then they have at least a weak metacognitive feeling of something task relevant. However, this is not the definition of 'guess' that is of interest in learning and memory research (this is akin to differing levels of confidence associated with familiarity). Rather, it is the

absence of confidence that ought to be isolated for study. Numerous ways of operationalising guess responses have been used in AGL studies to ensure this is the studied phenomenology. Recent iterations of experiments using structural knowledge attributions use the designation ‘random selection’ to clarify what is meant by a guess response and instructions to participants make it clear that this response should be used when they have no basis for their grammaticality judgment whatsoever which is analogous to flipping a coin to make their decision (e.g.: Neil & Higham, in press; Scott & Dienes, 2008, 2010c). Similarly, Dienes and Seth (2010b) introduced a new method of detecting unconscious knowledge in AGL: no-loss gambling. Using this procedure, participants indicate confidence in their grammaticality decisions either by betting on that decision in order to win a reward if correct or they can choose to bet on a transparently random process where there is a 50% chance of gaining a reward (such as picking one of two face-down cards, one of which indicates the reward). *Prima facie*, bets on the grammaticality decision index some degree of confidence in the response whereas bets on the random process indicate the absence of confidence. This plausibly eliminates both any tendency for ‘guess’ responses to be given when there is some confidence (if the participant has some degree of confidence they should choose to bet on their own judgment to maximise their potential reward) and biased language by clarifying what the researcher means by guess (that the participant expects their judgment to be no better than chance). Sixty per cent accuracy in bets on the random process was yielded using this procedure, satisfying the guessing criterion.

The contemporary states of the AGL and R/K literatures suggest that AGL is the more sensitive technique for researchers wishing to isolate responses based on guessing through more sophisticated measurement techniques and the implicit learning of novel rule-based material which appears more fruitful in satisfying the guessing criterion of unconscious knowledge. According to Scott and Dienes (2010a) and Dienes (2008a), the qualitative divide between the conscious and the unconscious occurs at the level of structural knowledge. Whether judgment knowledge shows the same separation is yet to be demonstrated. This concept features throughout this thesis.

Outline of the thesis

Apart from the present introduction and the concluding chapter, this thesis contains five chapters reporting empirical work. Four chapters use the AGL paradigm and one uses the R/K paradigm to demonstrate the utility of subjective measures of awareness in learning and memory studies and their relation to conscious and unconscious knowledge. The empirical chapters are based on manuscripts which have been submitted to international peer-reviewed journals. The results of the experiments reported in Chapters II and III support predictions derived from dual-process theory of recognition to the speed of different types of responses in AGL. Chapter IV explores the role of feedback on the conscious status of structural knowledge in AGL and suggests that implicit learning continues during test. Chapters V and VI investigate how different forms of thought (UTT and VO) affect different response types in an AGL and R/K study respectively.

Chapter II used the no-loss gambling measurement method to explore predictions derived from dual-process theory regarding the speed of conscious versus unconscious responses in AGL. Experiment one showed that in self-paced tests, responses that are not accompanied by a metacognitive evaluation of grammaticality (guess responses) take longer to be expressed than those which are accompanied by a conscious evaluation of grammaticality (responses made with some degree of confidence). However, Experiment two showed that guess responses do not suffer a speed accuracy trade-off under a strict deadline whereas responses that are made with some degree of confidence are less accurate under time pressure.

Chapter III extended the results of Chapter II with the use of more sensitive subjective measures of awareness than can be captured by the no-loss gambling method. Experiment one showed that the speed of responding in AGL is ordered by the conscious status of knowledge. The most rapid responses were those based on rules/recollection followed by intuition/familiarity and those based on random selection (guessing) were made most slowly. The effect held when differential confidence and accuracy levels were accounted for, suggesting

that distinctions in the speed of knowledge types are not reducible to a single dimension.

Response deadlines were used in Experiment two which revealed a double dissociation in how time pressure affects different forms of response accompanied by conscious judgment knowledge. Under a response deadline, the proportion of rule/recollection based responses was reduced (with a corresponding increase in guessing) compared to no deadline but the accuracy of such responses was retained. However, the proportion of intuition/familiarity based responses was equivalent in both deadline conditions but the accuracy of such responses was reduced.

Chapter IV explored the role of explicit feedback on incidentally acquired knowledge in AGL using a grammar cross-over design (Dienes & Altmann, 1997). Feedback increased the availability of conscious structural knowledge over the course of the experiment but had no detectable influence on its accuracy. Without feedback, the accuracy of responses based on unconscious structural knowledge with conscious judgment knowledge underwent a relative reduction but was maintained when feedback was provided.

Chapters V and VI applied predictions from other theories to implicit learning and recognition memory. Chapter V tested a prediction derived from unconscious thought theory which suggests a period of distraction after the acquisition of complex information (as in AGL) results in better decision making through the naturalistic weighting of rules compared to immediate decision making or rigorous amounts of conscious deliberation. Distraction did not improve the accuracy of grammar judgments accompanied by conscious judgment but did improve the accuracy of guess responses. Thus, the results suggest that any beneficial effects of unconscious thought may not always transfer to conscious awareness. Chapter VI used the R/K method to explore the antecedents of the conservative shift theory of verbal overshadowing in recognition. More conservative remember responses were given when describing visual stimuli at encoding than when copying the same stimuli (regardless of how easy or difficult the stimuli were to describe). Verbalisation also resulted in a shift from recollection to guessing, indicating fewer instances of recognition accompanied with a feeling of oldness; i.e. verbalisation increased the threshold for a feeling of recognition to occur.

Chapter II

No-loss gambling shows the speed of the unconscious

Abstract

This chapter investigates the time it takes unconscious versus conscious knowledge to form by using an improved “no-loss gambling” method to measure awareness of knowing. Subjects could either bet on a transparently random process or on their grammaticality judgment in an artificial grammar learning task. A conflict in the literature is resolved concerning whether unconscious rather than conscious knowledge is especially fast or slow to form. When guessing (betting on a random process), accuracy was above chance and RTs were longer than when feeling confident (betting on the grammaticality decision). In a second experiment, short response deadlines only interfered with the quality of confident decisions (betting on grammaticality). When people are unaware of their knowledge, externally enforced decisions can be made rapidly with little decline in quality; but if given ample time, they await a metacognitive process to complete. The dissociation validates no-loss gambling as a measure of conscious awareness.

Introduction

How can we tell if someone is aware of their knowledge? Artificial grammar learning (AGL; Reber, 1967) is a particularly useful methodology to address this question as it demonstrably elicits both conscious and unconscious knowledge according to subjective measures of awareness (e.g. Dienes, 2008a; Gaillard, Vandenberghe, Destrebecqz, & Cleeremans, 2006; Johansson, 2009). Two types of knowledge are involved in sequence classification in AGL: structural knowledge and judgment knowledge (Dienes & Scott, 2005; Scott & Dienes, 2008). During the initial training phase of an AGL experiment, participants are exposed to rule-based sequences generated by the grammar in question. Structural knowledge is (either conscious or unconscious) knowledge of the structural consequences of the grammar (and can consist of rules, patterns of connection weights, chunks, or whole items taken as examples of the structure). During testing, participants classify further novel sequences in terms of their grammaticality (whether they conform to or violate the studied rules). Here, judgment knowledge is the (conscious or unconscious) knowledge constituted by such a judgment (i.e. the knowledge that the test item is or is not grammatical). When both structural and judgment knowledge are conscious, grammaticality decisions are based on hypothesis-driven rule-application or a conscious recollection process of recognised exemplars or bigrams, trigrams or other parts of exemplars encountered during training. Feelings of intuition or familiarity are expressed when structural knowledge is unconscious but judgment knowledge is conscious (e.g.: “I know I’m correct but I don’t know why”) (Norman, Price & Duff, 2006; Norman, Price, Duff & Mentzoni, 2007). When both knowledge types are unconscious the phenomenology is that grammar judgments are mere guesses; no conscious metaknowledge of what has been learned is expressed. Figure 1 depicts the relationship between the conscious status of these knowledge types and the associated phenomenology. (See also Scott & Dienes, 2010a, for a model of how structural and judgment knowledge develop in AGL; and Scott & Dienes, 2008, and Pasquali, Timmermans & Cleeremans, 2010, for models of how judgment knowledge may become conscious).

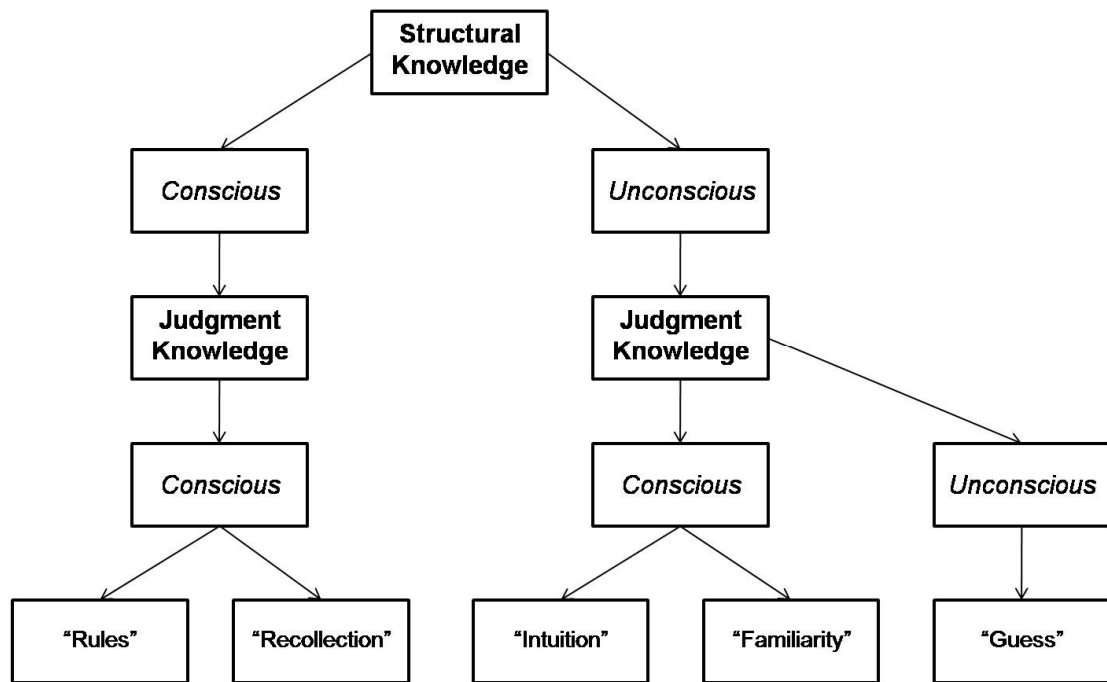


Figure 1: The relationship between the conscious status of structural and judgment knowledge and the associated phenomenology. The bottom row depicts self-reported structural knowledge attributions (see Dienes and Scott, 2005 and Scott and Dienes, 2008).

Numerous subjective measures of awareness have been used in AGL studies including verbal reports (Reber, 1967, 1969), confidence ratings made on binary (Tunney & Shanks, 2003) or continuous scales (Dienes, Altmann, Kwan & Goode, 1995) and structural knowledge attributions (Dienes & Scott, 2005; Scott & Dienes, 2008, 2010b, 2010c, 2010d; Wan, Dienes & Fu, 2008; see also Chen et al., 2011; Guo et al., 2011; Rebuschat & Williams, 2009). Recently, wagering has been used to assess conscious awareness. In their AGL study, Persaud, McLeod and Cowey (2007) asked participants to make high or low wagers using real or imaginary money after making a grammaticality decision. When correct, the wager was added to their total; when incorrect it was deducted. The procedure was presumed to motivate participants to make consistently high wagers whenever they felt more confident than a mere guess in order to maximise financial gain (Koch & Preuschoff, 2007). A tendency to wager high on accurate decisions would then provide an index of subjective awareness which is particularly useful for

researchers shy of overestimating unconscious knowledge, a potential pitfall of using verbal reports (Berry & Dienes, 1993). Persaud et al. found that despite a high level of overall performance (81% accuracy) participants made high wagers at a lower than optimal level. This was taken as evidence that participants were unaware of their knowledge (contrast Clifford, Arabzadeh & Harris, 2008).

However, this post-decision wagering procedure has been criticised due to the potential problem of risk (loss) aversion (Kahneman & Tversky, 1979). For the risk averse participant, losing a certain amount of money is more salient than gaining the same amount. This may encourage consistently low wagers to minimise loss when they do have some awareness of knowledge. In effect, this increases the rate of measured unconscious knowledge as operationalised by Persaud et al. (2007). Conversely, participants showing little risk aversion may be willing to wager large amounts on what, to them, seems like a random process. Thus, wagering without sensitivity to the risk aversion of the individual distorts conclusions drawn about the amount of conscious or unconscious knowledge expressed (Schurger & Sher, 2008). Indeed, Fleming and Dolan (2010) found that economic factors in post-decision wagering systematically influenced measures of perceptual sensitivity. Altering the wager size affected the proportion of low to high wagers which would lead one to change conclusions drawn about low or high levels of awareness. Furthermore, Dienes and Seth (2010b) compared a binary verbal confidence scale ('guess' vs. 'sure') against wagering in an AGL task while measuring risk aversion. They found a greater willingness to indicate confidence in responses using the verbal scale and that risk aversion significantly correlated with the amount of conscious knowledge as measured by wagering, but not as measured by verbal confidence.

In a second experiment, Dienes and Seth (2010b) introduced a new methodology to indicate the presence of unconscious knowledge in AGL: No-loss gambling. During the test phase, participants indicated their confidence in each grammaticality decision by either betting on the grammaticality decision (in order to win one sweet if correct) or on a transparently random process. If they chose the latter, they shuffled and then picked one of two face-down

cards, one of which had 'SWEET' printed on the invisible side, the other had 'NO SWEET'. Therefore choosing to bet on the cards meant there was a 50:50 chance the participant would add to their winnings. If one chooses to bet on the random process, rather than on the grammaticality decision, clearly no conscious preference for grammaticality or ungrammaticality is shown. This methodology bypasses the potential confound of risk aversion as participants never have the opportunity to lose their winnings but motivation to perform is maintained to maximise gains. Above chance sequence classification accuracy was displayed when choosing to bet on the random process, satisfying the guessing criterion of unconscious knowledge (Dienes et al., 1995).

In using verbal reports, participants may have their own idiosyncratic definition of 'guess' (Gardiner, Ramponi & Richardson-Klavehn, 1998). In everyday language, 'guess' can refer to a range of feelings of confidence. In classifying a test sequence some participants might say 'guess' when it felt as if they knew literally nothing relevant (the definition of 'guess' we are interested in – the absence of confidence) whereas others may take 'guess' to mean merely 'low confidence'. Merely 'low' confidence decisions can involve some awareness of knowing. However, betting on a random process shows a lack of conscious judgment: they are unaware of having any relevant structural knowledge. This is a literal guess as even if confidence in a decision was low, but not absent, it would still be worth betting on the grammar judgment to maximise reward rather than opting for the 50:50 gamble. Furthermore, this plausibly eliminates the problem of bias shown by any participant who says they are guessing but thinks they are not (Dienes, 2008a). In other words, no-loss gambling robustly distinguishes conscious from unconscious judgment knowledge (see Figure 1: No-loss gambling *prima facie* separates the guess response based on unconscious judgment knowledge from all other response types made with some degree of conscious judgment knowledge)

This chapter aims to improve on the methodology of no-loss gambling. In the original study by Dienes and Seth (2010b), participants attributed their knowledge (by betting on the grammar decision or on the cards) after the grammar judgment was made. It is possible that

awareness of judgment knowledge can be relatively transient. This conscious knowledge could be forgotten, or could degrade, between the two decisions leading one to bet on the cards despite having had conscious judgment knowledge. In effect this would increase the amount of unconscious knowledge as measured by betting on the cards. To address this problem it is simply a matter of ensuring both grammaticality classification and decision strategy are reported simultaneously while the test sequence is available to account for this possibility (cf. Tunney & Shanks, 2003, with verbal confidence ratings).

Further, no method can a priori prove itself from the arm chair just because it has good face validity. More broadly, the utility of the no-loss gambling methodology can only be verified if the results it yields are in line with theoretically motivated hypotheses (Dienes, 2004, 2008a). Thus, a further aim of the chapter is to demonstrate the utility of the method - by exploring a contradiction in dual-process theories of recognition memory. Dual-process theories posit that responses based on familiarity are made rapidly and automatically whereas recollection responses are relatively effortful and time-consuming due to strategic retrieval (e.g.: Jacoby, 1991; Yonelinas, 2002; see also the two-stage recollection hypothesis of Moscovitch, 2008). This view is supported by Hintzman and Caulton (1997), who found shorter response times for item recognition than modality judgments requiring conscious recollection of a previous learning episode. Furthermore, Boldini, Russo and Avons (2004) found that modality matches between learning and test (presumed to influence familiarity) under a strict deadline increased recognition compared to modality mismatches whereas under longer deadlines deep processing enhanced recognition compared to shallow processing (presumed to influence recollection). Such theories relate to AGL in that unconscious structural knowledge can express itself through familiarity and conscious structural knowledge can express itself through recollection. Consistently, in the context of AGL, Turner and Fishler (1993) found strict response deadlines had a greater impact on classification accuracy when participants had been instructed to search for grammar rules during training (thought to maximise explicit learning)

compared to those who simply memorised training sequences (thought to minimise explicit learning).

However, studies using the remember-know methodology (R/K; Tulving, 1985) have provided contradictory evidence, finding that in self-paced tests, fully recollective responses are made more rapidly than those based on just familiarity. (The R/K method involves subjects reporting on the phenomenology associated with recognition responses, with remember – R – responses indicating recollection, know – K – responses indicating just a feeling of familiarity, and guess – G – indicating no feeling of memory at all.) For example, Dewhurst, Holmes, Brandt and Dean (2006) found that after participants had studied word lists, subsequent ‘remember’ responses to test stimuli were made most rapidly, followed by ‘know’ responses (indicating familiarity without conscious recollection) then ‘guess’ responses (see also Dewhurst and Conway, 1994; Dewhurst, Hitch & Barry, 1998; Henson, Rugg, Shallice, Josephs & Dolan, 1999; Konstantinou & Gardner, 2005). Dewhurst et al. (2006) concluded that RTs reflect the time taken to make a decision based on the recollection or familiarity process and RTs may not reflect the actual retrieval process *per se* (i.e. the time differences in responses may be based on the information afforded to *metaknowledge* by R, K or G processes). The R/K method as applied to memory presumably taps similar processes as recollection and familiarity in AGL, though the interpretation is not exactly the same. R and K both involve conscious knowledge that an item was presented before, but familiarity- or rule-based -responses in AGL are not a commitment to an item having been presented before, but to the item being grammatical or ungrammatical. R responses are analogous with rule or recollection responses in AGL; both are dependent on consciously recognising that the item, or parts of the sequence, had been presented previously. K responses reflect a feeling, without conscious recollection, that the item had been presented previously and similarly in AGL familiarity responses reflect feelings of oldness of parts or aspects of a stimulus, without consciously recognising the parts of the sequence leading to that conclusion. However, in the current experiments the focus is on guess responses. A ‘guess’ response in memory occurs in the absence of conscious judgement of

whether the stimulus had appeared in training, and in AGL reflects the absence of conscious judgment of whether the sequence follows the grammatical structure from training (see Tunney, 2007, for implementation of the R/K methodology in an AGL task).

Wixted and Mickes (2010) argue that guess responses are made in R/K studies when the memory strength of a particular test item falls on the old/new decision criterion, in a similar manner to guess responses in AGL where the subjective familiarity of a particular test sequence is close to the subjective mean value acquired over the course of the experiment (Scott and Dienes, 2008). Gardiner, Ramponi and Richardson-Klavehn (2002) concluded from a meta-analysis that the performance of guess responses in R/K studies is typically at chance levels. This means that longer RTs for guess responses could sometimes reflect a lack of knowledge. This is not true of AGL studies where the guessing criterion is often satisfied (e.g.: Dienes et al., 1995; Dienes & Altmann, 1997; Dienes & Scott, 2005; Tunney & Shanks, 2003; Scott & Dienes, 2010b, 2010c), making it an ideal paradigm to investigate the time-course of how knowledge is expressed without conscious awareness of that knowledge. Thus, the primary aim of this chapter is to validate the no-loss gambling method by showing it distinguishes responses made with confidence and those made without confidence, by testing the apparent contradiction between hypothesised rapid unconscious responses and the results of standard R/K studies in accordance with dual process theory.

Experiment 1

Experiment 1 aimed to replicate the findings of Dienes and Seth (2010b) with an amended no-loss gambling methodology to ensure grammaticality classification and knowledge attribution were made simultaneously (cf. Tunney & Shanks, 2003, for verbal confidence). Thus there was no possibility of a conscious mental state degrading between the grammaticality decision and indicating confidence. Above chance accuracy for gamble responses would thus satisfy the guessing criterion of unconscious knowledge. In R/K studies, RTs to ‘guess’

responses are longer than ‘remember’ or ‘know’ responses (Dewhurst et al., 2006). Furthermore, guesses are, by definition, made in the absence of confidence and confidence is inversely related to RT (Petrusic & Baranski, 2003, 2009). As such, RTs for bets on a random process should be longer than those for bets on the grammaticality decision.

Method

Design and participants

Twenty-eight participants were recruited at the University of Sussex (79% female). Age range was 18 – 42 years ($M = 23.31$; $SD = 6.23$). Remuneration was either £3 or course credits. The two-grammar cross over design of Dienes and Altmann (1997) was used. Approximately half of the participants were trained on grammar A with ungrammatical sequences in the test phase taken from grammar B and vice versa.

Materials

The set of testing and training sequences were the same as used by Dienes and Scott (2005, Experiment 2; see appendix). Sequence length was between five and nine characters. The training lists were comprised of 15 training sequences from each grammar, combined and repeated three times in a random order. Thirty novel testing sequences from each grammar were used, again combined in a random order meaning participants viewed 60 testing sequences, 50% of which conformed to their respective training grammar. EPrime 2.0 software was used to display the stimuli and record responses. A fixed counterbalanced order was used in training and testing.

Procedure

Participants were tested individually at a computer and half viewed their list in reverse. During the training phase, the sequences appeared in the centre of the computer monitor (font Arial, point size 66) for 5000 ms before the screen went blank for 5000 ms. During this time the participant was required to write the sequence they had just seen on a piece of paper before the next sequence appeared. This procedure continued for all 45 sequences.

The participants were then informed that the sequences they had been reproducing obeyed a set of complex rules and they would be classifying further sequences in terms of their grammaticality. They were also informed about the response options. They were informed that if they had any confidence in their response, they would gain by betting on it: if they were correct they would win one sweet. If they had no confidence in their response they could bet on a 50:50 gamble instead for a chance to win one sweet. During the test phase, a fixation cross appeared on the screen for 2000 ms before the test string. Four options were available for each test sequence, corresponding to four number keys at the top of the keyboard. The options were as follows: 1. The sequence is grammatical and I will bet on this decision; 4. The sequence is NOT grammatical and I will bet on this decision; 7. The sequence is grammatical and I will bet on a 50:50 random process; 0. The sequence is NOT grammatical and I'll bet on a 50:50 random process. Thus, keys 1 and 4 indicated a "confident to some degree" response; 7 and 0 indicated a "guess" response. If participants chose to bet on their grammaticality decision, the fixation cross appeared before the next sequence was presented. If the participant was correct, one sweet was added to their total winnings (note that no feedback about accuracy was provided). If participants chose to bet on the 50:50 random process a message box appeared. There was a 50% chance the box would read 'You win' or 'You lose'. If the participant won, one sweet was added to their total winnings. At the end of the experiment, participants received their winnings (their choice of Smarties or Jelly Tots).

Results

Proportion of response types

All *t*-tests in both experiments are reported with two-tailed significance. One participant was excluded from the analyses for never choosing the 50:50 random process response. Bets on grammaticality decisions for the sake of brevity will henceforth be referred to as “confident” responses. This does not imply a high level of confidence, merely that participants had more confidence in these responses than betting on the random process (henceforth referred to as “guess” responses). Confident responses accounted for 58% of overall responses ($SE = 4.07$) and guesses accounted for 42% ($SE = 4.07$). The difference was marginally significant, $t(26) = 1.94, p = .063$.

Accuracy

The proportion of correct responses when confident was .73 ($SE = .04$), significantly higher than the chance value of .50, $t(26) = 6.07, p < .001, d = 1.57$. The proportion of correct responses when guessing was .60 ($SE = .03$), also significantly higher than chance, $t(26) = 3.42, p = .002$, Cohen’s $d = 0.93$, indicating unconscious knowledge by the “guessing criterion” of Dienes et al. (1995). The accuracy of responses with confidence was significantly higher than when guessing, $t(26) = 3.70, p = .001, dz = .75$, indicating some conscious judgment knowledge according to the “zero correlation criterion” of Dienes et al. (1995). These analyses were confirmed by employing signal detection measures, specifically d' , to give a standardised, bias-free measure of discrimination between grammatical and ungrammatical sequences. Values of d' greater than zero indicate reliable discrimination. However, hit and false alarm rates of 1 or zero are problematic for calculating d' , hence were corrected according to the recommendations of Snodgrass and Corwin (1988). Hit rate was calculated by the formula $(Hit + 0.5)/(Hits + Misses + 1)$ and false alarm rate by the formula $(False\ Alarm + 0.5)/(False\ Alarm + Correct\ Rejection + 1)$. Only participants who had data frequencies ≥ 1 for these cells were considered.

Discrimination (d') was significantly greater than zero for both confident decisions, ($M = 0.99$, $SE = .24$), $t(23) = 4.22$, $p < .001$, and guess responses, ($M = 0.34$, $SE = .13$), $t(22) = 2.62$, $p = .016$, confirming that discrimination was above chance for both response types. Furthermore, decisions made with confidence would be expected to result in better discrimination between grammatical and ungrammatical sequences than guesses, this trend was also confirmed, $t(18) = 1.85$, $p = .080$, $d_z = .42$.

Metacognitive monitoring

Table 1: *Categorisation of confidence responses for Type II signal detection analysis*

Accuracy	Confident	Guess
Correct	Hit	Miss
Incorrect	False alarm	Correct rejection

Note. 'Confident' refers to bets on the grammaticality decision and 'Guess' refers to bets on the 50:50 process.

A Type II signal detection analysis was conducted. While Type I signal detection indicates the degree to which a system can discriminate between noise events and signal-plus-noise events (here, ungrammatical and grammatical sequences), Type II signal detection gives a measure of metacognitive awareness; in this case that is for a participant to be aware (or unaware) of how well their confidence matches accuracy. Thus, responses were categorised as shown in Table 1 (cf. Tunney & Shanks, 2003; see also Higham, 2007 for Type II SDT in recognition and Timmermans, Schilbach, Pasquali & Cleeremans, 2012, for further discussion). Mean Type II d' was 0.32 ($SE = .10$), which was found to be significantly greater than zero, $t(25) = 3.25$, $p = .003$. Thus, participants' confidence adequately tracked likely accuracy.

Response times

RTs based on both confident and guess responses were not detectably different from being normally distributed, as shown by Kolmogorov-Smirnov tests, $D_s \leq .153$, $ps \geq .106$. Mean RT of confident responses was 4954 ms ($SE = 348$) and mean RT of guess responses was 5780 ms ($SE = 403$). The difference was significant, $t(26) = 2.20$, $p = .037$, $d_z = 0.42$. Multiple regression analyses were conducted which conformed to Lorch and Myers' (1990) individual equation method. Response type was used to predict RT while controlling for any effect of accuracy. Accuracy was not a significant predictor of RT, $\beta = -.03$ ($SE = .03$), $t(26) = 1.20$, $p = .243$. Response type was a significant predictor of RT, $\beta = .12$ ($SE = .05$), $t(26) = 2.62$, $p = .014$, confirming that guess responses were generally more time consuming than confident responses.

Discussion

The findings of Dienes and Seth (2010b) were replicated. Participants showed significantly above chance accuracy when betting on a random process, satisfying the guessing criterion of unconscious knowledge (Dienes et al., 1995). Furthermore, participants were willing to bet on a random process when grammaticality classification and decision strategy were made concurrently. This eliminated the possibility that a transient conscious judgment could degrade between sequence classification and reporting the decision strategy. Indeed the percentage of such "guess" responses in this experiment (42%) was higher than in the original study (28%). Unsurprisingly, responses based on betting on grammaticality ("confident" responses), indicating conscious judgment knowledge, resulted in higher accuracy than responses based on betting on a random process ("guess" responses), and the same trend was observed when signal detection measures were considered. The Type II d' analysis revealed that participants had awareness of when they had some form of knowledge (either familiarity/intuition or rule/recollection based as depicted in Figure 1) compared to guessing. Thus the no-loss

gambling procedure behaves as expected and measures what it is purported to measure. Furthermore, guess responses (hence, based on unconscious structural and judgment knowledge) were made more slowly than confident responses. Regression analyses confirmed guess responses took longer when any influence of accuracy was accounted for. Thus, when judgment knowledge is unconscious, knowledge of structure takes longer to be expressed than when judgment knowledge is conscious.

Experiment 2

Experiment 1 showed that responses made with conscious judgment knowledge are made more rapidly than when judgment knowledge is unconscious. However, dual-process theories suggest that unconscious responses are made more rapidly (Yonelinas, 2002). How do we solve this contradiction? Dewhurst et al. (2006) suggest that RTs to R or K judgments in the R/K paradigm do not reflect the time course of those processes *per se*, but rather the time taken to make decisions based on the information afforded by those responses to metaknowledge. Thus, it could be the case that the output of unconscious structural knowledge itself is a rapid process but without conscious judgment of that output, it takes time to be expressed. Following from this, if both structural and judgment knowledge are unconscious no matter how much time is given to classify a stimulus, a conscious feeling of accurate judgment (an intuitive feeling of ‘correctness’ or familiarity) will never form. This is shown by willingness to bet on random processes with above chance accuracy on grammaticality decisions in self-paced tests. Additionally, Dienes and Scott (2005) failed to find evidence that guess responses would become associated with conscious judgment knowledge over trials. Thus, it could be the case that participants await conscious judgment knowledge and only bet on a random process when a metacognitive feeling of having reached a clear resolution is not forthcoming, resulting in longer RTs for this response type. Therefore a strict response deadline would not interfere with the quality of responses associated with betting on a random process as the final judgment is not

consciously available and cannot optimise the decision. Conversely, if judgment knowledge itself takes time to be utilised, a response deadline should interrupt this process, resulting in reduced accuracy via sub-optimal decision making. Experiment 2 will distinguish these possibilities. Additionally, by combining the grammaticality and attributions together as a single response in Experiment 1, it could be the case that it is the metacognitive decision (i.e. deciding on a response strategy) that takes time to be expressed rather than the grammaticality judgment. Thus, Experiment 2 will also explore which of these decisions was the driving force behind the RT differences in Experiment 1.

Method

Design and participants

28 undergraduates from the University of Sussex participated in exchange for course credit (82% female). Age ranged from 18 – 36 years ($M = 20.00$; $SD = 5.15$). None had participated in Experiment 1. The same grammar cross-over design was used as in Experiment 1. The independent variables of interest were response deadline (short vs. none) and response type (guess vs. confident).

Materials and procedure

EPrime 2.0 software was used to display stimuli and record responses. The same training procedure was used as in Experiment 1. After training, participants were informed about the existence of rules underlying the grammar sequences before a practice block of trials commenced. This block was necessary for participants to practice responding appropriately to the set deadline and to be familiarised with the available response options. The practice block followed a similar format to those used by Johansson (2009) and Turner and Fischler (1993). This block consisted of 10 simple mathematics questions and the participants had to decide

whether the sum was correct or incorrect (e.g.: $2 + 7 = 9$; 50% of sums were correct). They were instructed to rest their fingers on the 1, 4, 7 and 0 response keys at the top of the keyboard between trials. An initial fixation cross was displayed on the screen for 2500 ms before the sum appeared. When participants were required to respond, a tone (11 kHz, duration of 100 ms) sounded through a pair of headphones concurrently with a backward mask of ampersands. In order to eliminate anticipatory responses, participants could not respond to the sum until the tone had sounded. Participants input their response by pushing the same response keys as in Experiment 1. 1. Yes – the sum was correct and I'll bet on this decision; 4. No – the sum was not correct and I'll be on this decision; 7. Yes – the sum was correct and I'll bet on a 50:50 random process or 0. No – the sum was not correct and I'll bet on a 50:50 random process. They were informed that these options would be more relevant for the testing trials. In the no deadline condition, the sum was displayed for 5000 ms before the tone and backward mask; these participants were informed they could not respond until after the tone but they could take as much time as they wished before making their decision. The 5000 ms display time was used to ensure a broad range of processing time compared to the short deadline condition. In the short deadline condition, the tone sounded and backward mask appeared after the sum had been displayed for 500 ms and participants were required to input their response as soon as they heard the tone. If participants in the short deadline condition took longer than 750 ms to make their response, a message appeared on the screen reading "Please respond faster". If they took less than 750 ms, the message would read "You're doing great".

After the practice block had finished the testing trials began. These followed the same format as the practice trials for both conditions. The same testing sequences, instructions for classifying sequences, and response key definitions were used as in Experiment 1. In the no deadline condition, sequences were displayed for 5000 ms before the tone and backward mask. In the short deadline condition, the sequence was displayed for 500 ms. Again, participants received their winnings at the end of the experiment.

Results

One participant from the no deadline condition misunderstood the instructions and was omitted from the analyses, leaving 12 participants in the no deadline condition and 15 in the short deadline condition. Mean RT under the short deadline after the sequence had disappeared was 641 ms ($SE = 73$) whereas after no deadline it was 1330 ms ($SE = 200$).

Proportion of response types

Guesses accounted for 42% ($SE = 3.60$) of responses and confident responses accounted for 58% ($SE = 3.60$). Under the no deadline condition, guesses accounted for 45% ($SE = 5.42$) of responses and 39% ($SE = 4.77$) under the short deadline. The difference was not significant, $t(25) = 0.90$, $p = .376$, $d = 0.35$, 95% CI [-8.34, 21.34]. There was no evidence that participants systematically changed their decision strategy according to deadline.

Accuracy

Figure 2 shows the proportion correct for the different conditions. A 2 x 2 (Response [guess vs. confident] by Deadline [short vs. none]) mixed ANOVA was conducted on the proportion of correct responses ($N = 27$). Confident decisions yielded higher accuracy ($M = .70$, $SE = .03$) than guess responses ($M = .60$, $SE = .03$). The difference was significant, $F(1, 25) = 11.51$, $p = .002$, $\eta_p^2 = .32$. No deadline resulted in higher accuracy ($M = .71$, $SE = .03$) than the short deadline ($M = .59$, $SE = .03$), $F(1, 25) = 8.47$, $p = .007$, $\eta_p^2 = .25$. The important finding was a deadline x response type interaction, $F(1, 23) = 8.84$, $p = .006$, $\eta_p^2 = .26$ (see Figure 2). The accuracy of confident decisions was significantly reduced under the short deadline ($M = .60$, $SE = .03$) compared to no deadline ($M = .81$, $SE = .01$), $t(25) = 4.27$, $p < .001$, $d = 1.16$. The same pattern was not found for guess responses. Accuracy under the short deadline ($M = .58$, $SE = .03$) was similar to that as under no deadline ($M = .61$, $SE = .04$), $t(25) = 0.55$, $p = .590$, 95%

CI [-.08, .14], $d = 0.21$. Critically, accuracy was significantly above chance for both response types under both deadline conditions, $t_s \geq 2.23$, $p_s \leq .042$ (note the 95% confidence intervals on Figure 2 do not cross the line representing chance performance). The short deadline did not detectably interfere with the quality of guess responses. When knowledge of both structure and judgment was unconscious, decisions could be made rapidly. Conversely, the short deadline had a substantial impact on the quality of confident responses – when judgment knowledge was conscious.

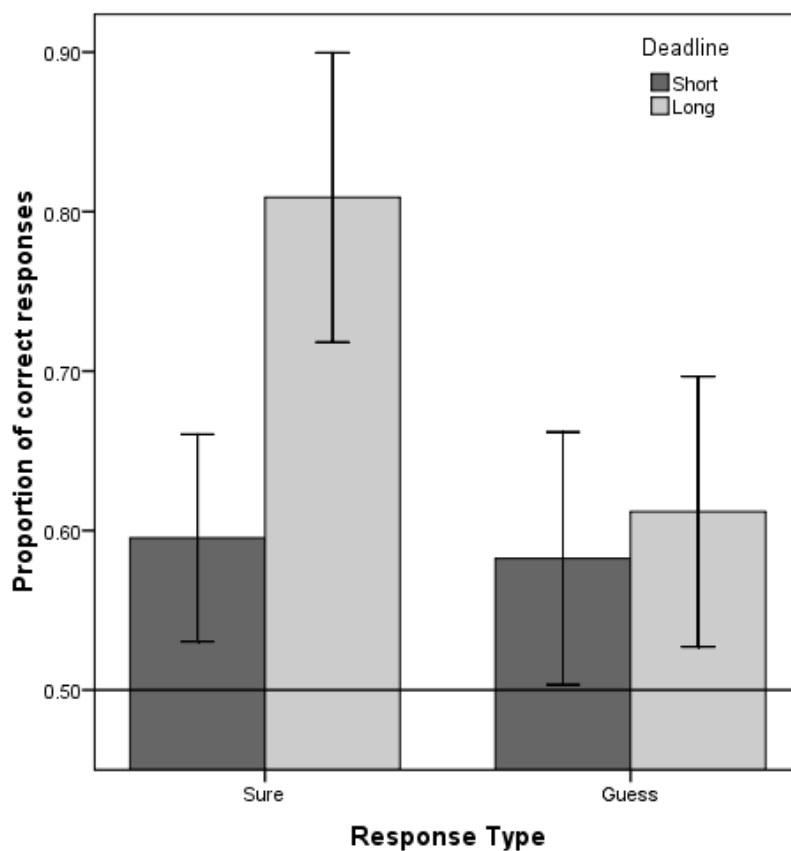


Figure 2: Accuracy as a function of response type and deadline. Bars represent 95% confidence intervals. The horizontal line shows chance performance.

Table 2: *Discrimination (d') as a function of deadline condition and response type. Standard errors appear in parentheses.*

	Confident	Guess
Deadline	0.51 (.15)	.37 (.19)
No deadline	1.94 (.32)	.61 (.22)

Note: 'Confident' refers to bets on the grammaticality decision and 'Guess' refers to bets on the 50:50 process.

Signal detection measures were again calculated as per Experiment 1. See Table 2 for descriptive statistics. A 2 x 2 (Response [guess vs. confident] by Deadline [short vs. none]) mixed ANOVA was conducted on d' . The no deadline condition resulted in significantly greater discrimination ($M = 1.28$, $SE = .20$) than the short deadline ($M = 0.44$, $SE = .18$), $F(1, 25) = 9.92$, $p = .004$, $\eta_p^2 = .28$. Discrimination of confident responses ($M = 1.29$, $SE = .17$) was higher than that of guesses ($M = 0.49$, $SE = .14$), $F(1, 25) = 21.53$, $p < .001$, $\eta_p^2 = .46$. The critical finding was a significant deadline x response type interaction, $F(1, 25) = 14.06$, $p = .001$, $\eta_p^2 = .36$. The discrimination ability of confident responses was significantly impaired under the deadline, $t(16.05) = 4.04$, $p = .001$, $d = 1.61$, and had no detectible effect upon guess responses, $t < 1$, replicating the analyses on the proportion of correct responses. Furthermore, d' was significantly greater than zero for confident responses under deadlines and guesses under the long deadline, $ts > 3.36$, $ps < .005$, with a similar trend for guessing under the short deadline, $t(15) = 2.00$, $p = .065$ (see Table 2).

Metacognitive monitoring

Type II d' was again calculated and an independent samples t-test (deadline vs. no deadline) was conducted on the score, revealing significantly better metacognitive awareness under the no deadline condition ($M = .71$, $SE = .11$) than the short deadline condition ($M = .04$, $SE = .12$), $t(25) = 4.01$, $p < .001$, $d = 1.57$. Furthermore, Type II d' was significantly greater than zero under no deadline, $t(11) = 6.23$, $p < .001$, which was not true under the short deadline,

$t(14) = 0.35$, $p = .734$, 95% CI $[-.21, .30]$. Thus, there was evidence that metacognitive monitoring of confidence was greater than chance would predict without the deadline. However, the non-significant result obtained for the deadline condition may suggest that the evidence is merely insensitive to detecting the same effect. Thus a Bayesian analysis was conducted. Bayes factors indicate continuous degrees of support for experimental hypotheses, where values greater than 3 indicate substantial support for the experimental hypothesis and values below 1/3 can be regarded as substantial evidence for the null (e.g. Dienes, 2008b, 2011; Jeffreys, 1961). It is commonly thought that Type I and Type II performance is based on the same information, though monitoring one's own performance is likely to be more difficult than Type I discrimination (e.g. Kunimoto, Miller & Pashler, 2001; Tunney & Shanks, 2003), thus Type II values cannot exceed Type I (also replicated in the current experiments). Therefore, the predictions that Type II awareness would be greater than chance (i.e.: zero) were modelled as a uniform distribution between 0 and the maximum Type I d' value obtained in the current experiments for the deadline and no deadline conditions (0.51 and 1.94 respectively). Under the deadline, the obtained Bayes factor was 0.39, approaching substantial evidence for the null hypothesis. Under no deadline, the obtained Bayes factor was base 3 log-transformed to aid interpretation (thus, values of -1 and +1 indicate substantial evidence for the null and alternative hypothesis respectively and 0 indicates no evidence either way), giving a logged-Bayes factor of 7.61, thus indicating substantial evidence in favour of the alternative hypothesis. Secondly, the hypothesis that the no deadline condition would result in better awareness of knowledge than under the deadline was modelled with a uniform distribution between 0 and the mean difference of Type I d' between deadline conditions as shown by the ANOVA main effect (0.83), yielding Bayes factor of 1308. This shows that without a deadline, participants had better awareness of when they were guessing or had confidence in their response compared to when under speeded pressure.

Discussion

The strict response deadline impacted on the quality of responses associated with betting on the grammaticality decision itself (confident responses), i.e.: those made with conscious judgment knowledge. No similar effect was found for responses made in the absence of conscious judgment (guess responses, associated with betting on a random process; though we cannot rule out a similar proportional reduction caused by short versus no deadline in guess responses as in confident responses). The detectable effect of deadline on confidence rather than guess responses is in accordance with dual-process theories of recognition memory insofar as knowledge that is not accompanied by metacognitive awareness can be elicited rapidly with virtually no decline in quality (note that the signal detection analysis indicated a trend towards greater than baseline accuracy for guesses under the deadline, although the analysis on the proportion of correct responses did indicate above baseline performance). The confident response still elicited knowledge under a strict deadline, the accuracy of which was comparable to the guess response. A period of around a second was demonstrably required for an optimal decision when judgment knowledge was conscious; the same was not true of responses made in the absence of conscious judgment knowledge. The results support the no-loss gambling method of measuring the conscious status of knowledge by showing the method picks out different types of knowledge, types that differ in ways consistent with relevant theory (in this case, dual process theory).

Interestingly, participants experienced judgment knowledge as conscious in a similar number of trials under a strict deadline as under no deadline (the short deadline increased guess responses by no more than 8%). An increase in the proportion of guess to confident responses under the strict deadline would have been theoretically plausible: participants may simply not have had time to generate conscious judgment knowledge under the short deadline. However, it seems if conscious judgment knowledge is going to be formed after a second, it will have at least started this process by half a second, allowing some confidence in the judgment. What is impaired by the deadline is not the awareness that some reliable process is being used, but the

reliability of that process, as shown by the Type II d' findings (the ability to reliably monitor metacognition was greater without a deadline than under the deadline. Furthermore, the evidence tentatively favoured the null when considering metacognitive monitoring under the deadline).

General Discussion

The first aim of this chapter was to improve the methodology of no-loss gambling (Dienes & Seth, 2010b) by having the confidence decision (what decision to bet on, grammaticality or a random choice) made at exactly the same time as the grammaticality decision. We showed in two studies that making the two decisions simultaneously led to a clear demonstration of unconscious knowledge by the guessing criterion (60% correct grammaticality choices when willing to bet on a random process rather than the grammaticality decision itself) – in fact, roughly the same amount of unconscious knowledge in terms of accuracy as originally found by Dienes and Seth with their sequential procedure (first grammaticality decision, then confidence). The fact that the simultaneous and sequential procedures yield the same results fits Tunney and Shank's (2003) finding with verbal confidence ratings.

The second aim of the chapter was to help validate the method by showing it picked out different knowledge types, types that differed in ways that fitted relevant theory. Indeed, the results presented here are in accordance with dual-process theories of memory (as e.g. interpreted by Dewhurst et al., 2006). It appears that the longer RTs associated with guess (and perhaps know) responses in R/K experiments are due to the information they afford to metacognitive judgment, not necessarily the knowledge of what has been learned (Dewhurst et al., 2006). When conscious judgment knowledge is not formed, self-paced tests reveal guess responses to be relatively time-consuming compared to when judgment knowledge is conscious. Yonelinas (2002) states that it is unsurprising that responses indexing familiarity are slower than those indexing recollection in R/K studies as participants are often instructed to use the 'know'

response if the item is not recollected, i.e. demand characteristics may play an important role in producing RT differences between guess, R and K responses. In effect this means both the familiarity and recollection responses are completed before a ‘know’ or ‘guess’ response is finally given. Similarly, in our case, it would have been fully permissible for participants to opt for rapid guess responses, yet this did not occur, perhaps for similar reasons – people wait to see if structural knowledge reveals itself to them. In fact, for these materials, unconscious judgment knowledge is formed in as good quality as it ever will be by 500 ms, whereas conscious judgment knowledge takes up to a second to fully form, providing a difference that is consistent with dual process theory and that therefore vindicates the measuring method.

The longer RTs for guess than sure responses are consistent with a contrasting single process theory of that difference that can be derived from Scott and Dienes (2010b), and seemingly inconsistent with the single-process theory by Cleeremans and Jimenez (2002) and Destrebecqz and Cleeremans (2001, 2003) who postulated that conscious as opposed to unconscious knowledge takes time to fully form. Scott & Dienes (2010b) present a single model account of conscious and unconscious judgment knowledge when based on unconscious structural knowledge. They found the most rapid RTs to grammaticality judgments were made when those judgments were based on the extremes of subjective familiarity, i.e.: those rated highly familiar or unfamiliar (see also the RT-distance hypothesis; Ashby, Boynton & Lee, 1994; and also evidence-accumulation models of decision making, e.g.: Lee & Cummins, 2004; Ratcliff, Gomez & McKoon, 2004; Ratcliff & Starns, 2009). RTs were longer to sequences in which familiarity was close to the mean. Furthermore, it was shown that familiarity predicted grammaticality judgments even when participants reported their decision strategy was a random selection. As a guess response means true indifference between endorsing or rejecting a sequence as grammatical, guesses reflect those responses where the to-be-classified stimulus is close to the mean value of subjective familiarity. Consistently confidence has been shown reliably to correlate inversely with RT in other paradigms (Petrusic & Baranski, 2003, 2009). One explanation of the long RTs for guess rather than sure responses is that discriminating

small differences in familiarity takes time. But such a theory would predict that short deadlines would hurt guess responses, contrary to these findings.

Somewhat paradoxically, despite the ‘natural’ time course of responses made with unconscious judgment knowledge being relatively long, this type of response can, when enforced, be made rapidly with little impact on quality. The proportion of accurate responses when betting on a random process under the strict deadline in Experiment 2 (.58) was virtually the same as the no deadline (.61) and the self-paced responding of Experiment 1 (.61), in support of dual-process theory. Experiment 2 also showed a large reduction in the quality of knowledge made with conscious judgment knowledge under the strict deadline. This helps solve the contradiction between dual process theories of memory and the findings that in self-paced tests unconscious knowledge takes longer to be expressed. Here the emphasis is on *expressed*; i.e.: the conscious judgment, or metacognitive experience, of that knowledge (cf. Moscovitch, 2008). Similarly, for the single process theory of Dienes and Scott (2010b), the greater time taken to use small differences of familiarity from the mean is not based on any inherent different time delay in using such differences compared to large ones; those differences can be used just as quickly as large ones. So how are the effects of deadline to be explained?

There are two possible explanations for why the deadline hurt conscious rather than unconscious judgment knowledge. Conscious judgment knowledge can be based on either conscious or unconscious structural knowledge. Thus, one hypothesis is that it is conscious structural knowledge (i.e. knowledge that goes beyond the overall familiarity of a string) that takes time to be fully used, consistent with the dual process models of Scott and Dienes (2010a) and Dienes (2008a), and this is why conscious judgment knowledge is overall harmed by a short deadline. As responses based on conscious structural knowledge are generally more accurate than those based on unconscious structural knowledge (e.g.: Dienes & Scott, 2005; Scott & Dienes, 2008, 2010a, 2010b, 2010d; contrast Scott & Dienes 2010c) it could be that conscious knowledge is comprised of more complex rules than unconscious knowledge (e.g.: application of higher-order n-grams or longer dependencies) that are inherently time consuming

to apply. If responses based on intuition or familiarity (unconscious structural knowledge) are based on simple, or relatively incomplete, knowledge (compared to conscious structural knowledge responses), responses based on this knowledge may take time to be expressed but are as well-formed as they will ever be in a short time. Alternatively, unconscious structural knowledge may be embedded in a connectionist network and can be applied with a single pass of activation while conscious structural knowledge may be applied serially. That is, the prediction of this hypothesis is that accuracy for responses with conscious judgment knowledge based on rules and recollections (conscious structural knowledge) would be harmed by a short deadline; but accuracy for responses with conscious judgment knowledge based on intuition and familiarity (unconscious structural knowledge) would be not be harmed by a short deadline.

The second hypothesis is that when the familiarity signal of unconscious structural knowledge is used metacognitively to classify strings, it becomes vulnerable. This may be because higher order representations of the first order familiarity state are linked by re-entrant loops (Edelman 1989; Kriegel, 2007; Lamme, 2006). Thus if deadlines interfere with the metacognitive process, the first-order state itself becomes modified, and thus the expression of the unconscious structural knowledge becomes distorted. Alternatively, the first order knowledge (familiarity) may not be altered by higher order states (cf. Rosenthal, 2000); nonetheless, once higher order states are used metacognitively if they become distorted and misrepresent lower order states, classification performance would be compromised. In either case (a causal integration of first and second order states or a simple misrepresentation of first order states by second order states), the deadline manipulation is predicted to interfere with confident responses based on intuition or familiarity. Of course, in the current experiment guess responses were not accompanied by, or integrated with, higher order states, which is why deadlines had little impact on accuracy. By this explanation, it may even be that conscious structural knowledge can survive the deadline manipulation. Given conscious structural knowledge is symbolic, some noise in its representation can be easily cleaned up (e.g. cf. Sun, 2002). However, familiarity is a continuous non-conceptual representation and it is unclear how

any noise introduced could be cleaned up – noise in familiarity can only degrade performance that is based on familiarity. Thus, if rules and recollections are particularly simple or strong, conscious structural knowledge could be unaffected by the deadline manipulation. Note that this possibility is opposite to the prediction outlined above, but still relies on a qualitative distinction between conscious and unconscious structural knowledge.

No-loss gambling provides a way of making clear to participants what is meant by a “guess” response – it means no better than random. But one can never be sure that any method always picks out just unconscious knowledge. Maybe people believe they have paranormal abilities (and can ‘will’ the random process to give a desired answer), or do not understand randomness, or probability match rather than respond optimally with their gambling (cf. Shanks, Tunney & McCarthy, 2002; note we did inform subjects that if they had any confidence in their response, they would gain by betting on it). Any measuring method can be criticized for the mere possibility it might sometimes get it wrong; the acid test is if in practice it gets it right often enough that it participates in theory-driven research, proving itself by the theories it can corroborate.

In sum, this chapter has demonstrated the usefulness of no-loss gambling by showing it survives more rigorous testing (simultaneous rather than successive judgments) and distinguishes qualitatively different knowledge types in ways consistent with dual process theory, a theory which is quite independent of the theory that the measurement procedure was based on (higher order thought theory, Dienes, 2008a; Rosenthal, 2000). Thus, both theory and measurement pull themselves up by their bootstraps (Seth, Dienes, Cleeremans, Overgaard & Pessoa, 2008).

Chapter III

The speed of metacognition: Taking time to get to know one's structural knowledge

Abstract

The time course of different metacognitive experiences of knowledge was investigated using artificial grammar learning. Experiment 1 revealed that when participants are aware of the basis of their judgments (conscious structural knowledge) decisions are made most rapidly, followed by decisions made with conscious judgment but without conscious knowledge of underlying structure (unconscious structural knowledge), and guess responses (unconscious judgment knowledge) were made most slowly, even when differences in confidence levels were controlled. In Experiment 2, short response deadlines decreased the accuracy of unconscious but not conscious structural knowledge. Conversely, the deadline decreased the proportion of conscious structural knowledge in favour of guessing. Unconscious structural knowledge can be applied rapidly but becomes more reliable with additional metacognitive processing time whereas conscious structural knowledge is an all-or-nothing response that cannot always be applied rapidly. These dissociations corroborate quite separate theories of recognition (dual-process) and metacognition (higher order thought and cross-order integration).

Introduction

What is the difference in the nature of conscious and unconscious knowledge? Artificial grammar learning (AGL; Reber, 1967) is a particularly useful methodology to help address this question as it demonstrably elicits both conscious and unconscious knowledge according to subjective measures of awareness (e.g. Dienes, 2008a; Gaillard, Vandenberghe, Destrebecqz, & Cleeremans, 2006; Johansson, 2009). Two types of knowledge are involved in sequence classification in AGL: structural knowledge and judgment knowledge (Dienes & Scott, 2005; Scott & Dienes, 2008). During the initial training phase of a typical AGL experiment, participants are exposed to rule-based sequences generated by the grammar in question. Structural knowledge is (either conscious or unconscious) knowledge of the structural consequences of the grammar and can consist of, for example, rules, patterns of connection weights, chunks, or whole items taken as examples of the structure learned during training. Before testing, participants are informed the sequences were generated by a series of complex rules before going on to classify further novel sequences in terms of their grammaticality (whether they conform to or violate the studied rules; typically 50% of sequences are grammatical at test). Here, judgment knowledge is the (conscious or unconscious) knowledge constituted by such a judgment which is directly expressed in sequence classification (i.e. the knowledge that the test item is or is not grammatical). When both structural and judgment knowledge are conscious, grammaticality decisions are based on hypothesis-driven rule-application or a conscious recollection process of recognised exemplars or bigrams, trigrams or other parts of exemplars encountered during training. Feelings of intuition or familiarity are expressed when structural knowledge is unconscious but judgment knowledge is conscious (e.g.: “I know I’m correct but I don’t know why”) (Norman, Price & Duff, 2006; Norman, Price, Duff & Mentzoni, 2007). When both knowledge types are unconscious the phenomenology is that grammar judgments are mere guesses; no conscious metaknowledge of what has been learned is expressed. (See Scott & Dienes, 2010a, for a model of how structural and judgment knowledge develop in AGL; and Scott & Dienes, 2008; Pasquali, Timmermans, and Cleeremans, 2010, for

models of how judgment knowledge may become conscious. See Figure 1 for the relationship between the conscious status of knowledge types and the associated phenomenology.)

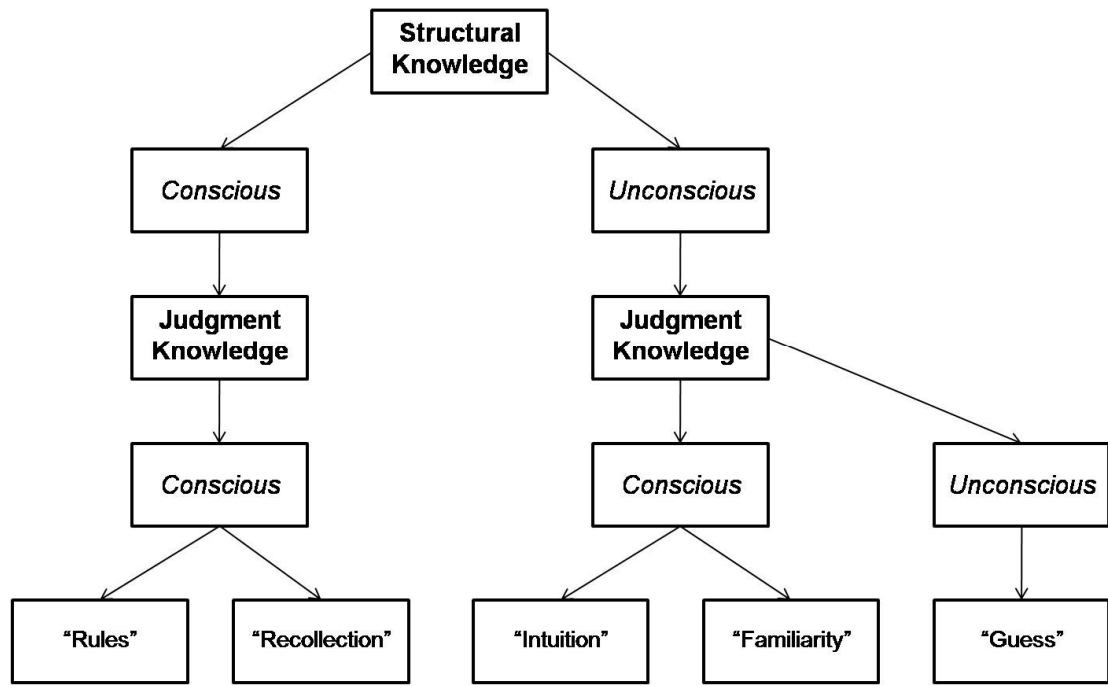


Figure 1: The relationship between the conscious status of structural and judgment knowledge. The bottom row represents self-reported structural knowledge attributions (Dienes & Scott, 2005; Scott & Dienes, 2008).

Numerous subjective measures of awareness have been used in AGL studies including verbal reports (Reber, 1967, 1969); confidence ratings made on binary (Tunney & Shanks, 2003) or continuous scales (Dienes, Altmann, Kwan & Goode, 1995); structural knowledge attributions (Dienes & Scott, 2005; Scott & Dienes, 2008, 2010a, 2010b, 2010c, 2010d; Wan, Dienes & Fu, 2008; see also Chen et al, 2011; Guo et al, 2011; Rebuschat & Williams, 2009) and wagering high or low amounts to indicate high or low levels of conscious awareness (Persuad, McLeod & Cowey, 2007). Recently, a new form of wagering as a measure of awareness has been introduced into the AGL literature to indicate the presence of unconscious knowledge, namely ‘no-loss gambling’ (Dienes & Seth, 2010b). During the test phase of AGL

studies using the no-loss gambling procedure, participants indicate confidence (thus, metacognitive awareness) in their grammaticality decisions by either betting on their decision and, if correct they gain a reward (e.g.: one sweet), or they can gain a reward by betting on a transparently random process with a 50% chance of winning. If one chooses to bet on the random process, rather than on the grammaticality decision, one is not aware of knowing the grammaticality of the stimulus, as it feels as if the grammaticality judgment is as reliable as flipping a coin (i.e.: it is a guess response). Conversely, when betting on the grammar decision itself, some degree of confidence and hence metacognitive awareness is indicated. Dienes and Seth found that when participants were betting on the random process, the accuracy of their grammaticality judgments was significantly above chance (around 60% correct responses in both cases), satisfying the guessing criterion of unconscious knowledge (Dienes et al., 1995). This shows participants could express unconscious structural knowledge when judgment knowledge was unconscious.

Chapter II used the no-loss gambling method to investigate an apparent contradiction in dual-process theories of recognition memory. Dual-process theories posit that responses based on familiarity are made rapidly and automatically whereas recollection responses are relatively effortful and time-consuming due to strategic retrieval (e.g.: Jacoby, 1991; Yonelinas, 2002; see also the two-stage recollection hypothesis of Moscovitch, 2008, and the continuous dual-process model of Wixted & Mickes, 2010). Several researchers have found evidence to support this view (e.g. Boldini, Russo & Avons, 2004; Coane, Balota, Dolan & Jacoby, 2011; Feredoes & Postle, 2010; Gronlund & Ratcliff, 1989; Hintzman & Caulton, 1997; McElree, Dolan & Jacoby, 1999; Yonelinas & Jacoby, 1996). However, studies using the remember-know methodology (R/K; Tulving, 1985) have provided contradictory evidence. R/K studies involve a learning phase where participants are presented with to-be-remembered stimuli (typically word lists). At test, they are required to discriminate between these previously seen targets and novel lures. When endorsing a stimulus as previously seen, the phenomenological basis for that decision is also reported; either remember (R) responses which indicate conscious recollection; know (K)

responses which indicate a feeling of familiarity without conscious recollection that the stimulus had been presented earlier; or guess (G) responses which indicate no feeling of memory at all even though the test item is accepted as old. Using this methodology, several researchers have found that in self-paced tests, R responses to endorsed stimuli are made most rapidly, followed by K responses and then G responses (e.g.: Dewhurst & Conway, 1994; Dewhurst, Hitch & Barry, 1998; Dewhurst, Holmes, Brandt & Dean, 2006; Duarte, Henson & Graham, 2008; Henson, Rugg, Shallice, Josephs & Dolan, 1999; Konstantinou & Gardner, 2005; Wheeler & Buckner, 2004; see also Sheldon & Moscovitch, 2010). The Dewhurst et al. (2006) interpretation of these findings is that RTs may not reflect the direct times of the actual retrieval process *per se*, but rather the information R, K and G responses afford to metaknowledge. A recollective experience allows a response without further delay, but a feeling of familiarity may be probed further.

The R/K method as applied to memory presumably taps into similar underlying processes as recollection and familiarity as AGL (see Tunney, 2007, for implementation of R, K and G responses in an AGL task). Many researchers (but not all, e.g. Donaldson, 1996; Dunn, 2004) subscribe to the view that R and K responses reflect qualitatively different forms of metacognitive commitment to a current test item having been previously presented. In a similar manner, recollection and familiarity in AGL reflect different metacognitive experiences that the current test sequence conforms to or violates the grammar structure from training. R responses in R/K and rules/recollection responses in AGL are consequents of consciously recognising the current item, or parts of the sequence, from training. K responses are given when there is a feeling of 'oldness' that the item has been presented previously without recollecting its occurrence and in AGL, intuition/familiarity responses are given when some aspect(s) of the test sequence result in a feeling of grammaticality or ungrammaticality ('oldness'/'newness' in an abstract sense of the current item's structure being old) but without consciously identifying those aspects that lead to that feeling. The interpretation of guess responses in both paradigms is also similar. Wixted and Mickes (2010) state that G responses are made when the memory

strength of an item falls near the old/new decision criterion. In AGL, guess responses are made when the subjective familiarity of a to-be-classified sequence is close to mean subjective familiarity of previously encountered sequences acquired during the course of the experiment (Scott & Dienes, 2008). However, a meta-analysis by Gardiner, Ramponi and Richardson-Klavehn (2002) concluded that the accuracy of guess responses in R/K studies is typically at chance. This is not true of AGL studies where the guessing criterion is often satisfied (e.g.: Dienes et al., 1995; Dienes & Altmann, 1997; Dienes & Scott, 2005; Dienes & Seth, 2010b; Tunney & Shanks, 2003). Furthermore, it has been shown that subjective familiarity can influence grammaticality judgments when participants report their decision strategy as a random selection (Scott & Dienes, 2008) which makes AGL an ideal procedure to investigate the respective time-courses of these different types of response.

Using the no-loss gambling method, Chapter II showed that in self-paced tests, ‘guess’ responses (as shown by willingness to bet on the 50:50 random process) took longer than responses made with some degree of conscious judgment knowledge (as shown by willingness to bet on the grammaticality decision) even when differences in accuracy were accounted for. In a second study, a strict response deadline (500 ms) was introduced into the test phase. It was found that the deadline only reduced the quality of responses made with conscious judgment knowledge and had no detectable effect on the quality of guess responses. Thus, it was concluded participants await a metacognitive feeling of judgment (e.g.: recollection or familiarity) to form. If this feeling is not forthcoming, only then do people opt to guess, i.e.: long RTs for guess responses are a reflection of the information afforded to metaknowledge (Dewhurst et al., 2006). However, when externally enforced, guess responses do not suffer a speed-accuracy trade off, which is not true of decisions made with some degree of metacognitive awareness. In the context of AGL this means that when both structural and judgment knowledge are unconscious, the decision quality is as good as it will ever be in around 500ms (for the materials used in Chapter II) but when judgment knowledge is conscious, extra time is needed to optimise the decision. It was also found that participants attempted to apply

conscious judgment (shown by the proportion of bets on the grammar decision to bets on the random process) in as many short deadline trials as no deadline trials showing that the process of metacognitive judgment has at least started in around 500 ms, but time is needed for that process to become optimally reliable (i.e.: under a deadline, participants think they are using a reliable judgment process to guide sequence classification when the reliability of that process has become compromised). However, as bets on the grammar decision in no-loss gambling do not distinguish between conscious and unconscious structural knowledge (i.e.: between intuition/familiarity and rules/recollection as shown on Figure 1), the findings of Chapter II raise further questions: is it conscious or unconscious structural knowledge that takes time to be applied? And what can we infer about the nature of the decision processes based on conscious and unconscious structural knowledge through investigating their time courses? We address these questions in two AGL experiments using self-paced responding (Experiment 1) and response deadlines (Experiment 2).

Experiment 1

Experiment 1 aimed to replicate and extend the findings of Chapter II using structural knowledge attributions in lieu of no-loss gambling (see method section for the structural knowledge attribution definitions used in the current experiments). These attributions allow for a greater range of responding when participants have some degree of confidence (metacognitive awareness) in their grammaticality decision and allow inference of the conscious status of structural knowledge subsumed within these decisions. As AGL and R/K presumably tap into similar decision making process, it is predicted that responses based on conscious structural knowledge (rules, recollection) should be most rapid, followed by those based on unconscious structural knowledge accompanied by conscious judgment knowledge (intuition, familiarity) and finally decisions made without conscious judgment knowledge (random selection, i.e.: guess responses).

Confidence is also inversely related to RT (e.g.: Petrusic & Baranski, 2003, 2009; Tunney & Shanks, 2003) and decisions based on familiarity or intuition are accompanied by lower confidence estimates than those based on rules or recollections whereas guesses are, by definition, made in the absence of confidence (e.g.: Dienes & Scott, 2005). This is also the pattern we would expect to observe in self-paced R/K studies (e.g.: Dewhurst et al, 2006). Theories which postulate (and methodologies which presume through their operationalisation) a qualitative difference between conscious and unconscious knowledge need to show that these reported types of knowledge are not reducible to a single dimension, such as confidence. If guesses, familiarity-based responding and recollective-based responding are associated with differing levels of accuracy and subjective confidence, this could be problematic for such theories. Thus, a second aim of Experiment 1 was to determine whether these response types have a degree of independence in terms of the time it takes to make a decision based on such knowledge types once confidence and accuracy are accounted for.

Method

Design and Participants

Fifty-five University of Sussex undergraduates participated in this study (ages ranged from 18 to 45 years). The two grammar cross-over design of Dienes & Altmann (1997) was used. Participants were trained and tested on either grammar A or B acting as control groups for one another. During testing, sequences from grammar A were used as ungrammatical sequences for grammar B and vice versa.

Materials

The set of testing and training sequences were the same as used by Dienes and Scott (2005, Experiment 2) and Chapter II (see appendix). Sequence length was between five and nine

characters. The training lists were comprised of 15 training sequences from the respective grammar, combined and repeated three times in a random order. Thirty novel testing sequences from each grammar were used, again combined in a random order meaning participants viewed 60 testing sequences, 50% of which conformed to their respective training grammar. A fixed counterbalanced order was used in training and testing. EPrime 2.0 software was used to display the stimuli and record responses.

Procedure

Participants were tested individually at a computer. During the training phase, the sequences appeared centrally in black text (font Arial, point size 66) for 5000 ms followed by a blank screen for 5000 ms. During this time the participant was required to write down the sequence as accurately as possible on a provided piece of paper before the next sequence appeared. The paper was removed after all 45 training sequences had been copied. Participants were then informed the sequences obeyed a complex set of rules and they were to classify further novel sequences in terms of grammaticality, half of which obeyed the same rules just studied. Each testing sequence required three judgments: grammaticality, attribution and confidence. For the grammaticality 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). RTs to this decision were recorded. Secondly, they were asked from where they felt their response arose (knowledge attribution) from five options based on Scott and Dienes (2008), corresponding to five numbers on the keyboard: random selection (1), intuition (3), familiarity (5), rules (7), recollection (9). The definition of these categories was as follows: *Random selection* – There is no basis for your response whatsoever. You may as well have flipped a coin to decide (this response corresponds to 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* – Your response is based on some rule(s) you learned earlier and you could say what these rules are if asked. *Recollection* – Your response is based on the fact you could or could not recollect seeing (parts of) the sequence earlier. Finally they were asked to enter their confidence in their grammar judgment choosing any number between 50% (a complete guess) and 100% (completely certain). Random selection responses were only allowed a value of 50% confidence. Participants were provided with a booklet of these definitions which they were allowed to refer to for knowledge attribution and confidence input. Once participants had given these responses for all 60 test sequences, the experiment was over.

Results

Responses based on familiarity or intuition were pooled into an ‘unconscious structural knowledge’ category; rules and recollection responses were pooled into a ‘conscious structural knowledge’ category; random selection responses (henceforth ‘guesses’) are responses based on unconscious structural and judgment knowledge and as such form their own category (the crucial difference between this response type and the unconscious structural knowledge category is that guesses are made without conscious judgment knowledge. The category labels used here are for the sake of brevity). See Table 1 for the percentage of response types. All *t*-tests in both experiments are reported with two-tailed significance unless specifically stated otherwise. Note the degrees of freedom change slightly between tests: not all participants used all attributions during testing so could not be entered into the corresponding analyses.

Table 1: *Percentage of responses, proportion of correct responses and response times (RT) for knowledge categories in Experiment 1. Standard errors appear in parentheses*

	Guess	Unconscious Structural Knowledge	Conscious Structural Knowledge
Responses	12% (2.00)	54% (2.94)	34% (3.12)
Accuracy	.59 (.04)	.72 (.02)	.80 (.02)
RT (ms)	6571 (389)	4772 (175)	3996 (153)

Accuracy of knowledge types

Accuracy scores (see Table 1) were entered into a one-way repeated measures ANOVA, finding a significant main effect of response type, $F(2, 82) = 19.04$, $p < .001$, $\eta_p^2 = .32$. Bonferroni adjusted pairwise comparisons showed that unconscious structural knowledge responses were significantly more accurate than guesses, $p = .004$. Conscious structural knowledge responses were significantly more accurate than both guesses, $p < .001$, and unconscious structural knowledge responses, $p = .004$, showing conscious judgment of both conscious and unconscious structural knowledge according to the zero correlation criterion. A robust Friedman's ANOVA was also conducted, and followed up with Wilcoxon signed ranks tests to determine between category differences, revealing the same pattern as the parametric tests (all $ps < .002$). The mean accuracy of guesses was above the chance value of .50, $t(45) = 2.54$, $p = .015$, $d = 0.37$ satisfying the guessing criterion of unconscious knowledge. Similarly, accuracy was above chance for both unconscious structural knowledge, $t(53) = 12.43$, $p < .001$, $d = 1.69$, and conscious structural knowledge, $t(48) = 12.78$, $p < .001$, $d = 1.86$.

Response times

RT data were z -transformed and outliers 2 SD beyond the mean were removed prior to analyses ($< 1.6\%$ data removed per knowledge category; see Table 1). Kolmogorov-Smirnov tests showed the distributions of RT data for all response types were not detectably different from normality, $Ds \leq .131$, $ps \geq .067$. Mean RT of conscious structural knowledge was 3996 ms

($SE = 153$); for unconscious structural knowledge, mean RT was 4772 ms ($SE = 175$); and for guesses mean RT was 6571 ms ($SE = 389$). (Note: RT data presented ignore accuracy). A one-way repeated measures ANOVA was conducted on RTs ($N = 42$) finding a significant effect of response type, $F(2, 92) = 42.70, p < .001, \eta_p^2 = .58$. Bonferroni adjusted pairwise comparisons revealed guesses to be significantly more time consuming than both conscious and unconscious structural knowledge responses, $ps < .001$. Unconscious structural knowledge responses also took longer to be expressed than conscious ones, $p < .001$. A robust Friedman's ANOVA was also conducted, and followed up with Wilcoxon signed ranks tests, revealing the same pattern as the parametric tests (all $ps < .001$).

Mean confidence in conscious structural knowledge responses was 76% ($SE = 1.14$) and 66% ($SE = 0.95$) in unconscious structural knowledge responses. The difference was significant, $t(48) = 10.92, p < .001$, and both were significantly higher than the 50% confidence associated with guess responses, $ts > 16.60, ps < .001$. Therefore it could be the case that the RT difference between response types is reducible to different levels of confidence. To determine whether knowledge attribution made a unique contribution to RT of responses beyond confidence, multiple regression analyses were conducted according to Lorch and Meyer's (1990) individual equation method. Response type was dummy coded (using guesses as a baseline, i.e. one variable coded guesses 0, unconscious structural knowledge 0 and conscious structural knowledge 1; another variable coded guesses 0, unconscious structural knowledge 1, and conscious structural knowledge 0) which was used to predict RT while controlling for confidence and accuracy. Accuracy was not a significant predictor of RT, $\beta = -.02 (SE = .03)$, $t(41) = 0.74, p = .462$, 95% CI $[-.08, .03]$. Confidence was a significant predictor of RT, $\beta = -.18 (SE = .03)$, $t(41) = 6.46, p < .001$. After controlling for accuracy and confidence, unconscious structural knowledge was found to be significantly faster than guessing, $\beta = -.24 (SE = .06)$, $t(41) = 4.10, p < .001, d = 0.37$. Similarly, after controlling for accuracy and confidence, conscious structural knowledge responses were also found to be significantly faster than guessing, $\beta = -.29 (SE = .07)$, $t(41) = 4.33, p < .001, d = 0.66$. The difference between the standardised beta

coefficients of conscious and unconscious structural knowledge responses was also significant, $t(41) = 2.09$, $p = .043$, $d_z = 0.32$, confirming the RT difference between guess, unconscious and conscious structural knowledge responses held once accuracy and confidence were accounted for.

Discussion

Responses based on conscious structural knowledge (rules, recollection) were made more rapidly than those based on unconscious structural knowledge accompanied by conscious judgment knowledge (intuition, familiarity), which in turn were made more rapidly than guesses (random selection). Multiple regression analysis confirmed that this effect held when both differences in confidence and accuracy were accounted for showing that these types of knowledge attributions are not reducible to a single dimension of confidence in terms of the time taken to express underlying structural knowledge (contrast the interpretations of confidence and RT in R/K studies proposed by Dewhurst et al., 2006, and Rotello and Zeng, 2008; see also Ratcliff & Starns, 2009; Rotello, Macmillan & Reder, 2004). These results replicate and extend those of Chapter II (see also Scott & Dienes, 2008, 2010b). Using the no-loss gambling method, it was unclear whether conscious or unconscious structural knowledge (accompanied with some degree of confidence) is expressed more rapidly in self-paced tests. These results show that it is conscious structural knowledge, followed by unconscious structural knowledge accompanied by conscious judgment and finally judgments made in the absence of any conscious preference for grammaticality.

Experiment 2

Self-paced tests show that, when judgment knowledge is conscious, underlying unconscious structural knowledge takes longer to be expressed than conscious structural knowledge.

However, it could be the case that the time differences do not reflect the time courses of those structural knowledge types *per se*, but rather the way they are used by metacognitive processes (consistent with the interpretation of dual process theory of e.g. Dewhurst et al, 2006). Chapter II revealed that short response deadlines (500 ms) only impacted on the quality of responses made with some degree of confidence. However, the no loss gambling method does not allow us to infer the conscious status of structural knowledge when participants bet on their grammar decision. Therefore, it is unclear whether the reduction in quality of these responses was due to difficulties in utilising conscious or unconscious structural knowledge under the deadline. We consider two opposing theories for the effect of deadlines on conscious versus unconscious knowledge.

On the one hand, dual-process theory suggests that consciously applying remembered rules may be relatively effortful (particularly if the rules held are fairly complex) compared to using automatic familiarity processes to classify sequences, thus making rule application a time consuming process. This possibility allows us to derive the hypothesis that a short response deadline would interfere with judgments based on rules or recollections, either via reduced accuracy of those decisions and/or via a decrease in the overall proportion of responses attributed to rules or recollection as participants simply would not have time to apply their conscious structural knowledge (and consequently, there would be an increase in attributions reflecting unconscious structural knowledge).

On the other hand, when structural knowledge is conscious, it is symbolic in nature meaning there is relatively little noise in the representation and the grammaticality decision is binary (e.g.: “I have (not) encountered XRV before, therefore the sequence is (not) grammatical”) (cf. Sun, 2002). Thus, conscious rules may be resistant to noise in that they can be easily cleaned up. In contrast, when structural knowledge is unconscious, the familiarity signal it affords to metacognitive judgment is a continuous, non-symbolic representation. Adopting a higher-order thought theory position (Rosenthal, 2000), it could be the case that this familiarity signal is vulnerable to interruption before the higher order process (conscious judgment) has

settled and a decision is made. This higher order state would therefore misrepresent the lower order state (unconscious structural knowledge). A similar prediction can be derived from cross-order integration theory (Kriegel, 2005, 2007). If the lower and higher order states are linked by re-entrant loops (Edelman 1989; Lamme, 2006), the deadline manipulation may interfere with the metacognitive process which would modify the lower order state, distorting the stored unconscious structural knowledge and lowering accuracy of this response type. These two possibilities effectively result in the same behavioural prediction that response deadlines would actually harm the accuracy of decisions based on unconscious structural knowledge.

Furthermore, as participants would, by definition, be unaware that their unconscious structural knowledge had become distorted, or misrepresented by their higher order judgment, the deadline manipulation would be unlikely to decrease the proportion of familiarity responses in favour of random responding (note that a deadline would not increase rule-based or recollective responding; the self-paced responding of Experiment 1 shows that no matter how much time is given to classify a particular sequence unconscious structural knowledge does not, itself, become conscious). The primary aim of Experiment 2 was to distinguish these theories of the effect of deadlines on conscious and unconscious structural knowledge. Would deadlines harm unconscious structural knowledge more than conscious or vice versa?

One important methodological factor to consider is the presence or absence of the grammar sequence during the testing phase. Conscious mental states about grammaticality may be relatively transient and could degrade between the grammaticality decision and knowledge attribution. However, a concurrent grammaticality and attribution design would be impractical when using five different knowledge attributions, particularly so when using response deadlines. The response deadline manipulation used here demands a sequential procedure, otherwise participants would have ten possible response options per sequence, which would be too difficult when they are required to respond as quickly as possible (and which would also presuppose the definitions of all categories are remembered throughout). Nevertheless, it could be the case that if the sequence remains present during and past the response deadline,

participants could make their grammar judgment based on unconscious structural knowledge before having time to consciously apply a rule and consequently select a rule or recollection attribution despite their grammaticality decision not being based on this strategy. Conversely, if the sequence is removed at the deadline, participants could have consciously applied a rule or recollective experience to the sequence which is subsequently forgotten and therefore would select an unconscious structural knowledge attribution. To account for these possibilities (of on-line vs. off-line knowledge attributions) two short deadline conditions were used: one where the grammar sequence disappeared at the deadline - sequence absent - and one where it remained for the grammaticality, attribution and confidence decisions - sequence present (see method section; see also Scott & Dienes, 2010b).

Method

Design and participants

Eighty-six new participants were recruited at the University of Sussex (ages ranged from 18-31 years) and were randomly assigned to one of the conditions: short deadline with sequence present, short deadline with sequence absent or no deadline. The same grammar cross-over design was used as in Experiment 1.

Materials and procedure

EPrime 2.0 software was used to display stimuli and record responses. The same materials and training procedure were used as in Experiment 1. After training, participants were informed about the existence of rules underlying the grammar sequences before a training block of trials commenced. The training block was necessary for participants to practice responding appropriately to the set deadline and to be familiarised with the three required responses to each test sequence. The practice block was the same as used in Chapter II and consisted of 10 simple

mathematics questions. Participants had to decide whether the sum was correct or incorrect (e.g.: $2 + 7 = 9$; 50% of sums were correct). An initial fixation cross was displayed on the screen for 2500 ms before the sum appeared. When participants were required to respond, a tone (11 kHz, duration of 100 ms) sounded through a pair of headphones. Participants responded by pushing the 1 (yes - correct) or 0 (no - incorrect) keys. In order to eliminate anticipatory responses, a response could not be entered until the tone had sounded. After making their response, participants chose an attribution then entered their confidence rating in their grammaticality decision as per Experiment 1 (they were informed these choices were more relevant for the testing trials and again were provided with a booklet of the definitions of the knowledge attributions and confidence which they were allowed to refer to during the non-speeded parts of the procedure). In the no deadline condition, the sum was displayed for 5000 ms to ensure a broad range of response times before the tone; these participants were informed they could not respond until after the tone but they could take as much time as they wished before making their decision. The sum remained on the screen until all three responses had been made. In the short deadline sequence present condition, the tone sounded after the sum had been displayed for 500 ms and participants were required to input their response as soon as they heard the tone. The sum remained on the screen during all three responses. In the short deadline sequence absent condition the sum disappeared when the tone sounded and did not appear for attribution or confidence input. If participants in the short deadline conditions took longer than 1000 ms to make their response, a message appeared on the screen reading "Please respond faster". If they took less than 1000 ms, the message would read "You're doing great". No time limits were set for attribution or confidence input.

After the training block had finished the testing block began. These followed the same format as the practice trials for all three conditions. In the no deadline condition the grammar sequence appeared on the screen for 5000 ms before the tone sounded. After participants made their grammaticality choice, the sequence remained on the screen for attribution and confidence input. The same procedure applied to the short deadline sequence present condition except the

tone sounded after 500 ms when participants were required to respond. In the short deadline sequence absent condition, the grammar sequence disappeared after the tone at 500 ms and did not reappear for attribution or confidence input. After 60 trials (50% grammatical), the experiment was over.

Results

Firstly the possibility of systematic differences between the short deadline conditions are considered before addressing the primary hypotheses, which are only concerned with responses made with conscious judgment knowledge. Intuition and familiarity responses were again pooled into an unconscious structural knowledge category and rules and recollection responses were pooled into a conscious structural knowledge category as per Experiment 1. Note the degrees of freedom throughout: not all participants used all available response types and thus these participants could not be entered into analyses with knowledge type as a within-subject variable (confidence data were also unavailable for one participant).

First the effect of deadline on the proportion of different knowledge types will be analysed; and then the effect of deadline on accuracy, which is our main concern. Guessing knowledge is then addressed and finally the effect on accuracy will be analysed according to effects on hits and false alarms for both Experiments 1 and 2.

Percentages of different knowledge types.

Table 2: *The percentage of responses and proportion of correct responses as a function of sequence status in the short deadline conditions and structural knowledge type. Standard errors appear in parentheses.*

	Unconscious structural knowledge		Conscious structural knowledge	
	Present	Absent	Present	Absent
Responses	51% (4.38)	57% (3.90)	33% (4.89)	24% (3.01)
Accuracy	.60 (.04)	.62 (.03)	.73 (.04)	.72 (.04)

Systematic differences acting on the proportion of response types or their accuracy (see Table 2) between the sequence present and sequence absent short deadline conditions were investigated. *T*-tests revealed no significant differences between the distribution of response types between present and absent conditions, $ts < 1.53$, $ps > .131$. Secondly, a 2 x 2 (sequence status [absent vs. present] by structural knowledge type [unconscious vs. conscious]) mixed ANOVA was conducted on the proportion of correct responses ($N = 53$). The mean proportion of correct unconscious structural knowledge responses was .61 ($SE = .02$) compared to .72 ($SE = .03$) for conscious structural knowledge. This expected difference was significant, $F(1, 51) = 18.65$, $p < .001$. There was no significant main effect of sequence status, nor a sequence status x response type interactions, $F_s < 1$. Thus, there was no evidence of a systematic difference acting on accuracy between the sequence present and absent conditions under the short deadline. Therefore, these data were pooled into an overall short deadline condition for the main analyses.

Table 3: *The percentage of response types according to deadline. Standard errors appear in parentheses.*

Structural knowledge type	No deadline	Short deadline
Guess	11% (1.96)	18% (1.98)
Unconscious	54% (3.16)	54% (2.92)
Conscious	36% (4.02)	28% (2.70)

Mean exposure time to the grammar sequence from onset until response under the short deadline was 1193 ms ($SE = 32$) and was 6983 ms ($SE = 191$) under no deadline (84% of responses were made within the short deadline constraint). T -tests were conducted in order to assess whether the deadline had an impact on the percentage of response types (see Table 4). There was no significant effect of deadline on unconscious structural knowledge responses, $t(84) = 0.20$, $p = .844$, 95% CI [-10.22, 8.37], $d = 0.05$, showing the proportion of this response type was similar between deadline conditions. The effect of deadline on the percentage of conscious structural knowledge responses was marginal, $t(84) = 1.69$, $p = .094$, $d = 0.38$. The short deadline led to a significant increase in guess responses, $t(84) = 2.29$, $p = .026$, $d = 0.53$, showing a shift from rule-based responding to guessing.

Effect of deadline on accuracy

Table 4: *Proportion of correct responses as a function of deadline and structural knowledge type (95% confidence intervals appear in parentheses). Descriptive statistics are based on unadjusted means.*

Structural knowledge	No deadline	Short deadline
Unconscious	.68 [.63, .73]	.61 [.57, .65]
Conscious	.68 [.58, .78]	.73 [.67, .79]

Table 4 reports the proportion of correct responses as a function of knowledge type and deadline. Independent t -tests were conducted on the proportion of correct responses (see Table

3), revealing a significant reduction in unconscious structural knowledge accuracy under the deadline, $t(87) = 2.08$, $p = .040$, $d = 0.48$; whereas no detectable difference in accuracy was found for conscious structural knowledge, $t < 1$. Further, the reduction in accuracy caused by the deadline was greater for unconscious than conscious knowledge, $t(80) = 2.51$, $p = .014$, $d = 0.58$.

However, mean confidence in conscious structural knowledge responses was 77% ($SE = 1.07$) and 68% ($SE = 0.81$) in unconscious structural knowledge responses. The difference was significant, $t(79) = 10.20$, $p < .001$. Therefore, an effect of deadline on knowledge type could be influenced by the relative difference in confidence between knowledge types. The difference in confidence between conscious and unconscious structural knowledge responses (henceforth 'C_{Diff}') was calculated ($M = 9.44$, $SE = 0.93$) and a t -test conducted in order to determine if there was an effect of deadline. No significant difference was found between the no ($M = 7.66$, $SE = 1.50$) and short ($M = 10.46$, $SE = 1.16$) deadline conditions, $t(78) = 1.46$, $p = .148$, 95% CI [-1.01, 6.60], therefore C_{Diff} was considered suitable to enter into the main analysis as a covariate. The difference in accuracy between unconscious ($M = .64$, $SE = .02$) and conscious structural knowledge ($M = .70$, $SE = .03$) was also calculated (henceforth 'A_{Diff}'). When A_{Diff} was regressed on C_{Diff} there was significant relation, $F(1, 77) = 12.21$, $p = .001$, $\eta_p^2 = .14$. Importantly, the difference in A_{Diff} between deadline conditions remained significant with C_{Diff} as a covariate, $F(1, 77) = 4.86$, $p = .031$, $\eta_p^2 = .06$.

There was a reduction in accuracy of 39% for unconscious structural knowledge due to the deadline manipulation (from 18% to 11% above baseline). The 95% confidence intervals for conscious structural knowledge allow us to rule out the same proportional change for this response type (a reduction of no more than 6% would be expected based on the lower bound of the 95% CI for conscious structural knowledge under the deadline). Accuracy was above chance for both response types under both short and no deadline conditions, $ts \geq 3.53$, $ps \leq .001$, thus both conscious and unconscious structural knowledge was expressed under both conditions (note the 95% confidence intervals in Table 4 do not cross the chance value of .50).

Effects of deadline on guessing knowledge

In the no deadline condition, the mean proportion of correct guess responses (those based on unconscious knowledge of both structure and judgment) was .51 (SE = .05, 95% CI, [.42, .61]), thus did not satisfy the guessing criterion of unconscious knowledge (the CIs are quite consistent with guessing knowledge) and was .45 (SE = .03, 95% CI, [.39, .51]) under the deadline (note that there was no detectable difference between deadline conditions, $t < 1.10$). This *prima facie* contradicts the results of Experiment 1, but note that in only 22 participants gave a guess response under the no deadline condition compared to 42 available for analysis in Experiment 1. A Bayes factor was calculated to determine whether this result reflected evidence for the null or data insensitivity, where values less than 1/3 indicate strong evidence for the null hypothesis; values over 3 indicate strong evidence for the alternative hypothesis and values around 1 indicate no substantial support either way (see Dienes, 2008b, 2011, for rationale). The difference between guess accuracy without deadline and baseline performance was .01 (SE of the difference = .05). In order to calculate a Bayes factor, a plausible effect size needs to be specified. A reasonable guessing knowledge accuracy estimate was calculated from similar studies using structural knowledge attributions after incidental learning conditions in AGL (Chapter V; Dienes & Scott, 2005; Scott & Dienes 2008; Scott & Dienes, 2010b), giving an arithmetic mean of .56. Thus, guessing knowledge without a deadline in Experiment 2 was modelled as a half normal, with the lower limit set at 0 (indicating baseline) and the SD set to .06, yielding a Bayes factor of 0.73, indicative of data insensitivity. However, under the deadline the proportion of performance was marginally worse than baseline, $t(54) = 1.75$, $p = .087$, $d = 0.24$. This point is returned to in the discussion.

Experiments 1 and 2: Effects of deadline on hits and false alarms

Table 5: Hit rate (HR), false alarm rate (FAR), discrimination (d') and response criterion (C) for conscious and unconscious structural knowledge responses as a function of deadline condition. Standard errors appear in parentheses.

Structural knowledge		HR	FAR	d'	C
Experiment 1					
Conscious		.72 (.03)	.25 (.03)	1.54 (.14)	0.08 (.08)
Unconscious		.70 (.03)	.32 (.03)	1.18 (.14)	0.00 (.07)
Guess		.51 (.03)	.34 (.03)	0.33 (.12)	0.16 (.08)
Experiment 2					
Conscious	Deadline	.61 (.03)	.28 (.04)	1.02 (.15)	0.19 (.07)
	No deadline	.66 (.04)	.28 (.04)	1.26 (.23)	0.10 (.09)
Unconscious	Deadline	.64 (.02)	.42 (.03)	0.63 (.11)	-0.09 (.05)
	No deadline	.67 (.03)	.32 (.03)	1.06 (.14)	0.03 (.07)
Guess	Deadline	.41 (.03)	.50 (.03)	-0.25 (.11)	0.14 (.06)
	No deadline	.44 (.05)	.37 (.05)	0.30 (.16)	0.28 (.11)

Note. Values of C reflect response criterion where positive values indicate a conservative response bias and negative values indicate a liberal bias. There are necessarily fewer participants included in the discrimination statistics than the proportion of correct responses and HR/FAR as d' calculations are dependent on both endorsing and rejecting at least one test stimulus.

The accuracy results obtained in both experiments were supplemented with a signal detection analysis. See Table 5 for descriptive statistics. Hit rates (correctly endorsing grammatical sequences as grammatical) and false alarm rates (erroneously endorsing ungrammatical sequences as grammatical) were calculated along with d' separately for the response categories. The value of d' corresponds to the difference in the standardised distributions representing noise trials (ungrammatical sequences) and signal-plus-noise trials (grammatical sequences) in terms of sequence endorsement. As values of d' increase, participants show a greater ability to discriminate between grammatical and ungrammatical sequences (where a value of 0 indicates no reliable discrimination). Hit rates (HR) and false

alarm rates (FAR) with a value of 1 or 0 are problematic for calculating these measures, thus the following formulae were used (from Snodgrass & Corwin, 1988): $HR = (H + 0.5)/(H + M + 1)$ where H and M refer to the frequency of hits and misses (incorrectly rejecting a grammatical sequence) respectively; and $FAR = (F + 0.5)/(F + CR + 1)$ where F and CR refer to the frequency of false alarms and correct rejections (correctly rejecting a sequence as ungrammatical). This adjustment can be understood as having a Bayesian prior that d' equals zero, worth two observations. Specifically, the prior corresponds to having 95% confidence that d' (and beta) lies between ± 3 .

For Experiment 1, the ANOVA on HR revealed a significant main effect of response type, $F(2, 82) = 17.90, p < .001, \eta_p^2 = .30$. Bonferroni adjusted comparisons showed a significantly higher HR for both conscious and unconscious structural knowledge over guesses, $ps < .001$; and no significant difference between conscious and unconscious structural knowledge, $p = .463$. The ANOVA on FAR revealed a significant main effect of response type, $F(2, 82) = 5.60, p = .005, \eta_p^2 = .12$. Bonferroni adjusted comparisons showed a significantly higher FAR associated with guesses than conscious structural knowledge, $p = .015$. The difference between unconscious structural knowledge and guesses did not reach significance, $p = .094$; nor did the conscious vs. unconscious structural knowledge comparison, $p = .440$. However, the differences in HR and FAR translated into a significant effect on d' , $F(2, 82) = 33.22, p < .001, \eta_p^2 = .45$. Bonferroni adjusted pairwise comparisons showed that conscious structural knowledge responses resulted in greater sensitivity to grammaticality than unconscious structural knowledge, $p = .022$, and guessing, $p < .001$. Unconscious structural knowledge responses also resulted in greater sensitivity than guesses, $p < .001$. The analysis presented here supports the analysis on the proportion of correct responses in Experiment 1.

For Experiment 2, responses made with conscious judgment knowledge were considered. As it was unclear whether a deadline would decrease hits or increase false alarms (or both), no *a priori* predications were made. Separate 2 (Structural knowledge type: unconscious vs. conscious) x 2 (short deadline vs. no deadline) mixed ANOVAs were conducted on HR and FAR respectively. No significant main effects or interactions were found

to act on HR, $F_s < 1.13$. There was no significant main effect of deadline on FAR, $F < 1.45$. However, there was a significant main effect of response type, with unconscious structural knowledge associated with a greater FAR ($M = .37$, $SE = .02$) compared to no deadline ($M = .28$, $SE = .03$), $F(1, 80) = 14.71$, $p < .001$, $\eta_p^2 = .16$. This finding was qualified by a significant response type x knowledge type interaction, $F(1, 80) = 5.21$, $p = .025$, $\eta_p^2 = .06$. The mean FAR of unconscious structural knowledge was .03 ($SE = .04$) higher than for conscious structural knowledge in the no deadline condition and was .14 ($SE = .03$) higher in the short deadline condition. Furthermore, considering unconscious structural knowledge responses separately, the short deadline significantly increased the FAR compared to no deadline, $t(84) = 2.16$, $p = .033$, $d = 0.50$.

The effect of deadline on FAR for unconscious structural knowledge translated into a significant effect of deadline on d' for unconscious knowledge: no deadline resulted in significantly better discrimination between grammatical and ungrammatical sequences than the short deadline, $t(84) = 2.05$, $p = .043$, $d = 0.46$ (note that d' of unconscious structural knowledge was significantly greater than zero under both deadline conditions, $t_s > 6.23$, $p_s < .001$). There was no detectable effect of deadline on d' for conscious structural knowledge, $t < 1$, (and d' for conscious structural knowledge was significantly greater than zero under both deadline conditions, $t_s > 5.56$, $p_s < .001$).

Discussion

The short response deadline reduced the *quality* of responses attributed to unconscious structural knowledge. There are two possible explanations for this effect. Firstly, it could be the case that without sufficient time, a conscious feeling of familiarity does not have time to settle when decisions are externally enforced. This feeling of familiarity therefore misrepresents lower order unconscious structural knowledge, in effect lowering the accuracy of decisions made in this manner (cf. Rosenthal, 2000). The second possibility is that if higher order representations

(judgment knowledge) are integrated with first order familiarity (structural knowledge) via re-entrant loops then deadlines interfere with this integrative process, distorting the lower order knowledge leading to inaccuracy (cf. Kriegel, 2007). Crucially, accuracy was above chance for unconscious knowledge under the short deadline showing it is possible for familiarity-based unconscious knowledge to be elicited rapidly, as is predicted by dual process theory. However, without sufficient time for metacognitive judgment of that knowledge to complete, decisions are made at suboptimal levels, as suggested by higher order thought and cross-order integration theories and in support of the hypotheses. The reduction in accuracy of this knowledge type was mainly driven by an increase in false alarms (erroneously endorsing ungrammatical sequences as grammatical). As the percentage of trials attributed to unconscious structural knowledge was largely unaffected by deadline (54% in both cases) participants still experience a metacognitive feeling of familiarity but the reliability of that feeling is compromised without sufficient processing time (see also Glöckner & Witteman, 2010).

Secondly, the deadline marginally reduced the *proportion* of overall conscious structural knowledge attributions and increased the likelihood of random selection responses, in support of dual process theory. Although the deadline did not affect the accuracy of conscious structural knowledge within Experiment 2, the trend towards a greater proportion of overall random selection responses suggests that when conscious structural knowledge is not at maximal strength (or perhaps the known rules are too complex), people do not have time to apply it. The same effect was not found for unconscious structural knowledge responses; presumably because rule based responding in AGL is an all-or-nothing categorical process which is not true of using continuous familiarity signals to guide responses (Sun, 2002). When participants do not have the time to apply conscious structural knowledge they may feel as if they know nothing at all (and opt to guess; cf. the two-stage recollection hypothesis of Moscovitch, 2008). The reduced proportion of conscious structural knowledge attributions could also reflect differences in conscious decision strategies used by participants. Presumably, grammaticality decisions where a sequence could be classified on the basis of a relatively small

amount of information (e.g.: the appearance or absence of a salient bigram remembered from training) would be made relatively rapidly due to the small amount of information required to satisfy the decision criterion of that participant compared to more complex rules (e.g.: evaluating a sequence on the basis of its global repetition structure where more elements in the sequence would require matching to the stored conscious structural knowledge) and the trials involving these more complex evaluations are the driving force behind the reduction in conscious structural knowledge responses. Related to this point, it is possible that for some trials under the deadline participants attempted to apply conscious structural knowledge rapidly, realised their judgment was incorrect then (mis)reported their decision strategy was a random selection (explaining the poor performance of guesses under the deadline in Experiment 2). However, this ‘demand characteristics’ interpretation still supports the hypothesis that when structural knowledge is conscious it can take time to be applied; only after making their grammar decision did participants realise they were incorrect and misreported their attribution as random selection (i.e.: they became consciously aware of their accurate structural knowledge only after the deadline). In fact, guess responses under the deadline were marginally *poorer* than baseline. There is no *a priori* reason for this to be the case, and stands in stark contrast with results found using the no-loss gambling procedure. Thus, the favoured interpretation is the misreporting of knowledge as, when given sufficient processing time, a rule or recollection response would have been made else the performance of guessing knowledge would be no different from chance as a minimum. The one-step procedure may therefore be the more sensitive technique to elicit veridical knowledge when the judgment is unconscious (the conscious-unconscious judgment knowledge distinction motivates no-loss gambling as a methodology) where the two-step procedure allows for more opportunities to misreport knowledge states, but is sensitive to the conscious-unconscious structural knowledge division. A more direct investigation of how response deadlines impact on one- and two-step procedures and how this affects scale sensitivity is a matter for future investigation (see Wierzchoń, Asanowicz, Paulewicz & Cleeremans, 2012 for recent work on response scale sensitivity and

confidence in AGL; see also Gardiner et al., 2002, for a discussion of the factors affecting guessing in recognition memory studies).

The reduction in performance of unconscious structural knowledge compared to conscious structural knowledge was not mediated by the relative difference in confidence between these knowledge types, further suggesting a qualitative difference between these knowledge types. The dissociations found in Experiment 2 strengthen the conclusions of Experiment 1, specifically that the phenomenological differences captured in conscious and unconscious structural knowledge attributions reflect qualitatively distinct states, which have some degree of independence from the levels of confidence associated with those states in terms of the amount of time such knowledge takes to be applied.

General Discussion

The current experiments replicate and extend the findings of Chapter II. In self-paced AGL tasks, responses based on both conscious structural and judgment are made most rapidly, followed by responses based on unconscious structural knowledge accompanied with conscious judgment and those made without any metacognitive preference for grammaticality are made most slowly. Importantly, it was also found that the different types of structural knowledge attribution showed a qualitative difference in terms of RTs once accuracy and confidence were partialled out. This finding has good face validity: it would be possible to have high confidence in a strong feeling of familiarity (as in the “butcher on the bus” phenomenon; Mandler, 1980; see also Wixted & Mickes, 2010) or have low confidence in weakly held or overly-complex consciously recognised rules (Dienes, Scott & Seth, 2010). Experiment 2 showed dissociations between structural knowledge types in terms of how response deadlines affect such knowledge. Firstly, when responses were based on intuition or familiarity, the response deadline reduced the quality of those decisions, but not the overall proportion of these response types (54% of responses were attributed to intuition or familiarity under both short vs. no deadline conditions

and in the self-paced responding of Experiment 1). The main driving force behind the reduction in accuracy of this knowledge type was an increase in false alarms (cf. Johansson, 2009). This finding has similarities to those of Higham, Pritchard and Vokey (2000) who found an increase in the acceptance of ungrammatical sequences as grammatical under a response deadline. Here we extend the account to responses reported with subjective measures of awareness (there was an increase in false alarms associated with intuition and familiarity based responses under the deadline but not with recollection or rule-based responses; furthermore, the deadline increased the false alarm rate of unconscious structural knowledge relative to conscious structural knowledge). Response deadlines are thought to encourage non-analytic processing of the stimuli where the item is evaluated as a whole rather than its constituent parts (analytic processing). It seems reasonable that an increase in false alarms may be a result of such non-analytic processing where simply surface elements are evaluated and not the relations between them which leads to an increase in accepting ungrammatical sequences as grammatical (see also Johansson, 2009; Scott and Dienes, 2010b). See also the proposal of ‘matching intuition’ (Glöckner & Witteman, 2010) which assumes intuitively based judgments (here, unconscious structural knowledge accompanied by conscious judgment knowledge) suffer time-costs with an increasing number of learning experiences (i.e.: exemplars encountered during training would be the incidental learning experiences in AGL)

The opposite pattern was found for responses based on rules and recollection where knowledge goes beyond the overall familiarity of the sequence. The quality of those decisions was retained but the number of responses was reduced in favour of random selection (the proportion of conscious structural knowledge attributions in the no deadline condition and the self-paced responding of Experiment 1 were comparable at 36% and 34% respectively, whereas in the short deadline condition this was reduced to 28% of responses). These findings corroborate both dual process theory and higher order thought and/or cross-order integration theories and suggest a qualitative difference between responses based on conscious and unconscious structural knowledge. That structural knowledge attributions behave in ways in line

with hypotheses based on both higher-order thought theories (which motivated their initial introduction in Dienes and Scott, 2005) and dual process theory (a quite separate theory) further validates their use as a measurement tool.

The difference between the proportion of correct responses for conscious structural knowledge in Experiment 1 (.80) and the no deadline condition of Experiment 2 (.68) seems surprising. However, this is actually a virtue of the manipulation used in Experiment 2: the no deadline condition resulted in the same accuracy level for conscious and unconscious structural knowledge, which satisfies the recommendations of Lau and Passingham (2006) in that there was no confound in first order performance (see also Lau, 2008). Thus, the method and analysis employed in Experiment 2 is the most controlled way of assessing the effect of the response deadline upon types of structural knowledge. Extending this argument, equal accuracy levels for conscious and unconscious structural knowledge speak against a simple notion of a graded quality of representation (i.e. placing unconscious and conscious structural knowledge on a continuum) when a further deadline manipulation can dissociate them (see Seth, Dienes, Cleeremans, Overgaard & Pessoa, 2008). Conscious and unconscious structural knowledge attributions do appear to capture qualitatively distinct states, at least in terms of the time taken to make decisions based on those processes. Returning to the difference in accuracy for conscious structural knowledge between Experiment 1 and the no deadline condition of Experiment 2¹, the difference between grammar sequence onset and response for a conscious structural knowledge response in Experiment 1 and for a response under no deadline in Experiment 2 was approximately 3 seconds. This raises the possibility that too much conscious deliberation in AGL harms conscious structural knowledge, possibly to a greater extent than unconscious structural knowledge. Reduced performance following and arbitrarily enforced period of rumination is a well verified effect in other domains (e.g. Wilson & Schooler, 1991;

¹ An independent samples *t*-test between the accuracy of conscious structural knowledge in experiment 1 and the no deadline condition of experiment 2 indeed reveals a significant difference, $t(40.31) = 2.19, p = .034$ (degrees of freedom corrected for a homogeneity of variance violation). The same is not true of unconscious structural knowledge, $t(81) = 1.33, p = .188$; and, furthermore, the interaction reaches significance, $F(1, 76) = 4.14, p = .039$.

Waroquier, Marchiori, Klein & Cleeremans, 2010), and such results are often interpreted under verbal overshadowing (Schooler & Engstler-Schooler, 1991; Chin & Schooler, 2008) or unconscious thought (Dijksterhuis, 2004; Dijksterhuis & Nordgren, 2006) theoretical frameworks (see also Payne, Samper, Bettman & Luce, 2009 for the advantages of self-paced conscious thought over an enforced period of thought). Although this is a preliminary result, further research could more thoroughly explore the role of rumination on implicit learning on a per-trial basis (see also Chapter V for work on different modes of thought between training and testing in AGL).

With respect to the findings of Chapter II, we can now state that when both structural and judgment knowledge are unconscious, the quality of decisions based on these knowledge types is as good as it will ever be in roughly 500 ms (for the materials used). However, in self-paced tests, this response type takes longest to be expressed as people await a metacognitive feeling of judgment; if this feeling is not forthcoming then they opt to guess. Nonetheless, the process of conscious judgment at least begins in the same time frame when participants have metaknowledge about the sequence. When structural knowledge is unconscious, but is accompanied with conscious judgment knowledge, decisions can be made in roughly 1000 ms, but extra time is required for judgment knowledge to be optimally reliable, likely due to the time costs involved in evaluating continuous familiarity signals. Finally, when both types of knowledge are conscious, decisions appear binary in nature but people may have trouble applying this all-or-nothing response before 1000 ms (and indeed may realise errors in their classification after this time). These findings are broadly in line with those in the recognition memory literature. In a review paper, Yonelinas (2002) states that familiarity responses are impaired before 750 ms and are largely optimal in around 1000 ms, whereas recollection requires additional retrieval time. We extend this account to AGL, where test stimuli are evaluated on the basis of similarity to exemplars, rather than recollecting the actual previous presentation and presumably this is why the RTs are slightly longer than those reported in R/K studies.

Notably, the results presented here are *prima facie* at odds with those of Turner and Fischler's (1993) AGL study where participants were either trained in a memorise condition (similar to the incidental learning used in the current experiments which is thought to minimise explicit learning of the grammar) or instructed them to search for rules (thought to maximise explicit learning). They found that a response deadline in the test phase had a larger impact on the accuracy of participants in the rule-search condition, that is under conditions more likely to give rise to conscious structural knowledge. However, there is no reason to believe memorise vs. rule search conditions are process pure in that both elicit conscious and unconscious structural knowledge (e.g.: Dienes & Scott, 2005) and the efficacy of rule search instructions in improving the quality of knowledge may be dependent on the difficulty of the grammar in question (Reber, 1976). Thus, rule search instructions may be more likely to lead to a shift in processing style rather than substantially affecting accuracy depending on the experimental materials. Future research could more systematically investigate the impact of different AGL training conditions on different knowledge types and their robustness vs. vulnerability to time pressure (see also Domangue, Mathews, Sun, Roussel & Guidry, 2004; Sallas, Mathews, Lane & Sun; 2007).

In summary, this paper shows that the 'natural' time course of knowledge in AGL is expressed in order of its conscious status: firstly conscious structural knowledge (rule or recollection based responding), then unconscious structural knowledge accompanied by conscious judgment (feelings of intuition or familiarity) then unconscious structural and judgment knowledge (self-reported random responding, i.e.: guessing). Self-paced tests reveal the time courses of these knowledge types are not reducible simply to differing levels of confidence associated with such knowledge. Response deadlines show intuitive or familiarity based responding benefits from additional evaluation time in order to reach maximum quality whereas, in circumstances where it can be applied, rule-based responding is well formed in around 1000 ms, even when differences in relative confidence levels are accounted (and indeed, extending this period beyond a self-defined optimal amount of thought may detract from its quality). However, when conscious structural knowledge is not strong enough, or is too

complex, people have trouble applying it rapidly and opt to report their decision as a random selection. The differences in the time courses of these knowledge types and how deadline pressure affects such knowledge suggests a qualitative distinction between conscious and unconscious structural knowledge.

Chapter IV

Explicit feedback maintains implicit knowledge

Abstract

The role of feedback was investigated with respect to conscious and unconscious knowledge acquired during an implicit learning task (artificial grammar learning; AGL). Participants were exposed to letter sequences which, unbeknownst to them, obeyed structured regularities before classifying further sequences as obeying or disobeying that structure. Sequences which disobeyed the learning structure conformed to an alternative structure. One group was provided with explicit veridical feedback about the accuracy of their classification judgments and the other was not. Feedback led to an increase in the amount of reported conscious knowledge of structure (derived rules and recollections) but did not increase its accuracy whereas it maintained the accuracy of unconscious knowledge of structure (intuition or familiarity-based responses) which otherwise degraded. Results support a dual-process account of AGL and suggest that implicit learning of the to-be-rejected structure at test contaminates familiarity-based classifications whereas feedback allows competing familiarity signals to be contextualised, which is incompatible with theories that consider familiarity a memory process that occurs regardless of intent.

Introduction

People often rely on intuitive feelings when performing all kinds of everyday tasks requiring high levels of expertise and often times the processes guiding behaviour are difficult to introspect upon due to implicit influences (Cleeremans, 2006). Knowledge is said to be implicit or unconscious (here, the terms are used interchangeably) when one is unaware of its presence or nature despite its potential influence on behaviour (e.g. Dienes, 2008a, 2012). Many skills thought to have an implicit component rely on repeated practice or exposure rather than through direct instruction. This is thought to minimise explicit learning of the material and the intention to learn is not required (e.g.: Allen & Reber, 1980; Berry & Dienes, 1993; Dienes & Berry, 1997a, 1997b; Domangue, Mathews, Sun, Roussel & Guidry, 2004; Higham, Vokey & Pritchard, 2000; Mathews, 1997; Reber, 1989; Sallas, Mathews, Lane & Sun, 2007; Rebuschat & Williams, 2009; Scott & Dienes, 2010a; Ziori & Dienes, 2006, 2008). During the acquisition of implicit knowledge - ‘implicit learning’ - one may not be aware of learning anything at all. Such learning episodes may also result in feelings of intuition or familiarity or experiences of “rightness” or “wrongness” without knowing directly from where those feelings stem (e.g.: Dienes, 2012; Mangan, 2003; Neil & Higham, in press; Norman, Price, Duff & Mentzoni, 2007). This is contrasted with explicit knowledge where the individual is aware of what has given rise to their judgments and explicit learning where learners engage in rule-based analytic processing or hypothesis testing.

One of the most common experimental paradigms used to investigate implicit learning and the resultant knowledge is artificial grammar learning (AGL; Reber, 1967), where participants are exposed to a series of letter sequences generated by a rule-based system. After several minutes exposure, they are informed of the presence of rules before going on to classify further novel sequences in terms of conformity to or violation of the studied structure. Performance is often around 65% accuracy where 50% represents baseline. However, successful worldly discrimination does not allow inference of the conscious status of knowledge that led to that behaviour. It is perfectly possible for someone to be confident that a sequence is

(un)grammatical - which entails awareness that the *judgment* itself constitutes knowledge - but this does not necessitate that they are aware of that sequence's features which make it (un)grammatical, i.e.: the underlying *structural* knowledge which led to the grammaticality judgment (Dienes, 2012).

This structural and judgment knowledge distinction motivated the use of structural knowledge attributions in implicit learning (Chen et al., 2011; Guo et al., 2011; Dienes, Baddeley & Jansari, 2012; Dienes & Scott, 2005; Jiang et al., 2012; Kiyokawa, Dienes, Tanaka, Yamada & Crowe, 2012; Fu, Dienes, & Fu, 2010; Neil & Higham, in press; Rebuschat & Williams, 2009; Scott & Dienes, 2008, 2010a, 2010b, 2010c 2010d; Wan, Dienes & Fu, 2008). Structural knowledge attributions reflect different metacognitive experiences of knowledge (see Figure 1). Rules and recollection responses index conscious structural knowledge where one can explicitly represent the aspects of a given stimulus which motivate the grammaticality judgment. Intuition and familiarity responses index conscious judgment of unconscious structural knowledge when one has a metacognitive feeling related to grammaticality (or accuracy) but not knowledge of their source. Random selection responses reflect the phenomenology of mere guesses, where no conscious metaknowledge regarding grammaticality is experienced. Structural knowledge can be incidentally learned during a standard AGL training phase where participants are unaware of any structure to learn. See Dienes (2012) for a discussion on the conscious versus unconscious status of knowledge in relation to the learning of statistical and other regularities.

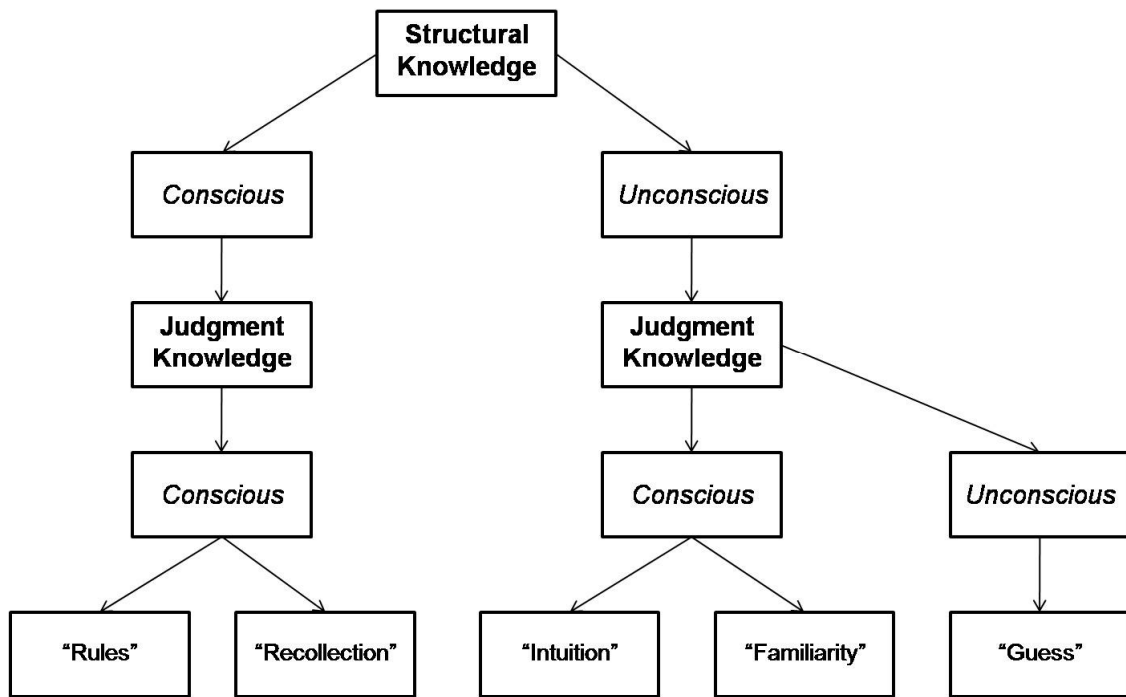


Figure 1: The relationship between the conscious status of structural and judgment knowledge. The bottom row represents self-reported awareness of knowledge. “Rules” and “recollection” reflect explicit knowledge. “Intuition”, “familiarity” and “guess” reflect degrees of awareness of implicit knowledge (Scott & Dienes, 2010a)

Laboratory-based empirical studies suggest that unconscious knowledge is relatively weak compared to conscious knowledge in terms of its performance (e.g.: Dienes & Scott, 2005; Scott & Dienes, 2008, 2010a, 2010b, 2010d; contrast Scott & Dienes, 2010c). However, outside of the experimental context, in speaking your native language you are making use of your structural knowledge of that language, and this knowledge is not necessarily open to introspection. You can know whether or not a sentence spoken in your native language is grammatical, and be highly confident in this judgment without having conscious access to the complete syntactical structure of your language (structural knowledge). Similarly, it is often difficult to explain to a second language learner why an alternative version (judgment) of what they are saying (structure) would be better, suggesting some unconscious structural knowledge (Dienes, 2008a). Native language learning is principally acquired through incidental experience as opposed to explicit teaching of specific language rules, such as grammar (Mathews, 1997)

and children learn the main grammatical constructions of their native language by about age five despite being unaware of a grammar to be learned. Connectionist models suggest that at least some language structure can be learned through its statistical properties (e.g.: Plunkett & Juola, 1999) and the implicit learning of natural language facets has been demonstrated empirically (e.g.: Chen et al., 2011, Guo et al., 2008; Kovic, Westermann & Plunkett, 2008; Neil & Higham, in press; Rebuschat & Williams, 2009; Ziori & Dienes, 2008; see also; Robinson, 2010, who argues AGL is more akin to native language than second language learning, and Gomez & Gerken, 2000, for a discussion of artificial language learning in infants), even of non-statistical properties (Jiang et al. 2012; Rohrmeier, Fu & Dienes, in press). Learning the rules that govern natural language has an implicit component and this form of exemplar based exposure is the most common training technique used in AGL. However, with sufficient practice the kind of expert-level implicit knowledge used in natural language expression is flexible: an infinite number of grammatically correct sentences can be created and the content of those sentences can be used in novel contexts.

Mathews (1997) suggests that low confidence in unconscious knowledge (and perhaps its relatively poor performance) obtained during AGL and other implicit learning tasks may be characteristic of the early stages of implicit knowledge acquisition, whereas with sufficient practice implicit knowledge can be used with high levels of confidence and accuracy (Cleeremans, 2006). Of course, it is beyond the scope of many laboratory-based single session or small scale studies to train participants to ‘expert’ levels of unconscious knowledge (however one may reasonably define ‘expert’). Nevertheless, one feature of natural language acquisition and its use is that speakers are consistently given explicit feedback about the performance of their structural knowledge by virtue of being understood and responded to by others (and sometimes given actual corrective feedback when in the early stages of learning a language). Yet, explicit feedback is not given in typical AGL studies after the point that participants are instructed to apply their knowledge, which may detract from ecological validity when drawing conclusions beyond the experimental methodology. In one of the few published studies to

provide feedback in AGL, Mathews et al. (1989) trained one group of participants under typical memorisation instructions. This group proceeded to classify 800 sequences (with feedback) over a number of sessions and after each 10-trial block reported their subjectively derived classification rules. A second untrained group of participants used these rules to classify sequences themselves, thereby assessing their validity. These participants showed above baseline performance, suggesting the first group reported some relevant conscious structural knowledge. Both groups also showed improvement over the course of the experiment. However, the performance of the second group did not reach the level attained by the first, evidence that not all of the first group's knowledge was subsequently reported. However, it is uncertain whether this is due to the potential issue of withholding information in free report (see Berry & Dienes, 1993) or if some of the structural knowledge that the first group had was unconscious, thus not available to introspection. Consequently the influence of feedback upon structural knowledge types remains uncertain (see also Dolan & Fletcher, 1999). Additionally, AGL studies are frequently conducted in a single session, rather than over weeks as in the Mathews et al. case. In many cases multiple testing sessions may simply be impractical or beyond the scope of the project. In a separate single session study that provided feedback about responses in AGL, Scott and Dienes (2008, Experiment 2) encouraged participants to be more confident in their grammaticality judgments. They showed that confidence encouragement (suggesting to the participant that their grammar judgments were generally correct) reduced the number of responses attributed to random selection (guessing) and increased intuition and memory (recollection) attributions. It also reduced the quality of responses attributed to guessing to chance levels, through a process of familiarity calibration (Scott & Dienes, 2010a). However, it remains unclear what role veridical feedback regarding accuracy plays with respect to the conscious status of structural knowledge.

Scott and Dienes (2010a) present a dual process theory of knowledge acquisition in AGL. At test, participants undergo a process of familiarity calibration in which grammaticality decisions become more tightly linked to the subjective mean familiarity of test sequences

encountered thus far. Further exposure to sequences allows for increasingly reliable estimates of mean familiarity and smaller discrepancies from mean familiarity to be taken as a reliable method to determine grammaticality; allowing for conscious judgments of unconscious structural knowledge to be made (intuition, familiarity). Additionally, once participants are able to make these feeling-based distinctions, conscious structural knowledge can be derived. For example, an explicit rule is developed when the realisation is made that all preceding sequences containing a particular element had been classified as (un)grammatical. The results of Scott and Dienes (2008) suggest that encouraging confident convictions accelerates this process. However, this feedback was non-veridical as it was provided regardless of accuracy. Providing feedback about the actual accuracy of grammaticality decisions should allow conscious structural knowledge to be derived rapidly. The dual process model predicts that under deliberate learning (“rule-search”) conditions, conscious structural knowledge would emerge earlier in the test phase than through incidental learning through considered effort to learn subjectively pertinent sequence elements. Dienes and Scott (2005) found rule-search instructions increased the amount of reported conscious structural knowledge but without increasing its accuracy; here we make the prediction that feedback should serve much the same purpose as rule-search instructions. However, the key distinction is that derived conscious structural knowledge should develop over the course of the experiment after incidental learning; that is when the intention to learn is absent. Using the same materials here, we can derive the prediction that there should be an increase in the number of conscious structural knowledge attributions, without necessarily increasing its accuracy.

A different prediction regarding unconscious structural knowledge can be derived through AGL methodological considerations. One common method thought to ensure adequate control is the grammar cross-over design. One group is trained on grammar A and another on grammar B. Ungrammatical sequences for use at test are then selected from the opposing grammar. This method has been used in a number of studies (e.g. Brooks & Vokey, 1991; Dienes & Altmann, 1997; Dienes & Scott, 2005; Scott & Dienes, 2008, 2010b, 2010c, 2010d).

However, the dual-process theory of Scott and Dienes (2010a) allows for learning at test, which may extend to implicit learning of the regularities of to-be-rejected sequences. Increasing familiarity with the to-be-rejected grammar would result in their subjective familiarity distributions being drawn together, resulting in reduced sensitivity to grammaticality and impairing discrimination as test trials progressed. Wan et al. (2008) demonstrated strategic application of unconscious structural knowledge of two grammars when given the appropriate intention to do so. Importantly, people could use familiarity to distinguish the grammars, showing feelings of familiarity can be contextualised. Feedback could similarly aid participants contextualise familiarity signals, helping discrimination between the grammars to be maintained.

An alternative, but not mutually exclusive, prediction stems from dual process theory of recognition. There is an emerging literature postulating that the processes underlying classification in AGL are similar (although not identical) to those which contribute to performance in recognition memory tests (e.g.: Higham, 1997; Higham et al., 2000; Scott & Dienes, 2010b Tunney, 2007, 2010; Vokey & Higham, 1999). Dual process theories of recognition memory posit a qualitative difference between recollection and familiarity processes, reminiscent of the dual process theory of AGL under consideration here (for reviews, see e.g.: Diana, Reder, Ardnt & Park, 2006; Wixted & Mickes, 2010; Yonelinas, 2002; Yonelinas, Aly, Wang & Koen, 2010). Over the course of an intermediate term delay, forgetting associated with familiarity occurs more rapidly than forgetting associated with remembering (Hockley, 1992; Hockley & Consoli, 1999; Yonelinas & Levy, 2002; see also Yonelinas, 2002). Thus, a familiarity signal driving unconscious structural knowledge sequence classification could decay over the test phase, lowering the endorsement rate of sequences generally and leading to more conservative responding. As AGL classifications are dependent on similarity to exemplars, feedback could maintain a familiarity signal that would otherwise degrade.

Considering unconscious structural knowledge, contaminated familiarity with to-be-rejected sequences predicts a reduction in discrimination without feedback (whereas

contextualisation through feedback maintains grammaticality sensitivity), whereas familiarity decay predicts a shift to more conservative responding without feedback. Furthermore, feedback should increase the development of conscious structural knowledge over the test phase to a greater extent than with without feedback. These possibilities will be tested.

Method

Design and Participants

Eighty-seven members of the University of Sussex participated (forty-seven in the feedback group and forty in the no feedback group). The two grammar cross-over design of Dienes & Altmann (1997) was used. Participants were trained and tested on either grammar A or B. At test, sequences from grammar A were used as ungrammatical sequences for grammar B and vice versa.

Materials

The set of testing and training sequences were the same as used by Dienes and Scott (2005, Experiment 2; see appendix). Sequence length was between five and nine characters. The training lists were comprised of 15 training sequences from each grammar, combined and repeated three times in a random order. Thirty novel testing sequences from each grammar were used, combined in a random order meaning participants viewed sixty testing sequences, 50% of which conformed to their respective training grammar. EPrime 2.0 software was used to display the stimuli and record responses. A fixed counterbalanced order was used in training and testing, with half of the subjects shown the list in reverse order.

Procedure

Participants were tested individually at a computer. During the training phase, training sequences appeared centrally in black text (font Arial, point size 66) for 5000 ms followed by a blank screen for 5000 ms. During this time the participant was required to write down the sequence as accurately as possible before the next sequence appeared. Participants were then informed the sequences obeyed a complex set of rules and they were to classify further new sequences in terms of grammaticality, half of which obeyed the same rules. At test, each sequence required three judgments: grammaticality, attribution and confidence. For the grammaticality 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 from where they felt their response arose (knowledge attribution) from five options based on Scott and Dienes (2008), corresponding to five numbers on the keyboard: random selection (1), intuition (3), familiarity (5), rules (7), recollection (9). The definition of these categories was as follows: *Random selection* – There is no basis for your response whatsoever. You may as well have flipped a coin to decide. *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* – Your response is based on some rule(s) you learned earlier and you could say what these rules are if asked. *Recollection* – Your response is based on the fact you could or could not recollect seeing (parts of) the sequence earlier. Finally they were asked to type their confidence in their grammar judgment choosing any number between 50 and 100% (where 50% corresponds to a complete guess and 100% to complete certainty). After these three decisions, participants in the feedback group would see a message box before the next sequence reading ‘Your grammar judgment was CORRECT’ or ‘Your grammar judgment was INCORRECT’ based on accuracy. Participants in the no feedback condition did not see a message box.

Results

Intuition and familiarity responses both reflect instances where sequence classification is based on unconscious structural knowledge accompanied with conscious judgment knowledge and as such were pooled into an ‘unconscious structural knowledge’ category for the purposes of analysis. Rules and recollection responses reflect instances where structural knowledge is conscious and as such were pooled into a ‘conscious structural knowledge’ category (see Figure 1). Random selection responses are instances where both structural and judgment knowledge are unconscious, and therefore form their own ‘guess’ category (the conscious status of judgement knowledge is the key difference between the ‘guess’ and ‘unconscious structural knowledge’ categories used here). In order to investigate effects over the course of the experiment, trials 1 – 30 were pooled into block 1 and trials 31 – 60 were pooled into block 2. Note the degrees of freedom throughout: not all participants used all category types in the relevant block of the experiment, thus could not be entered into the corresponding analyses (two blocks were considered appropriate in order to maximise use of the data). Mean confidence in conscious structural knowledge responses was 78%, and in unconscious structural knowledge was 67%. Neither feedback group nor block significantly impacted upon confidence, thus this measure is not discussed further.

Response types

Analyses of the percentages of responses attributed to each category required the use of separate ANOVAs as these percentages sum to 100%. Thus, three 2 x 2 (Block [block 1 vs. block 2] x Feedback [feedback vs. no feedback]) mixed ANOVAs ($N = 87$) were conducted on the percentage of guess, unconscious and conscious structural knowledge responses (see Table 1 for descriptive statistics). No significant main effects or interactions were found for guess responses, $F_s < 1$. The ANOVA on unconscious structural knowledge responses revealed a marginal effect of block, with more unconscious structural knowledge responses in block 1 (M

= 55, $SE = 2.49$) than block 2 ($M = 52$, $SE = 2.64$), $F(1, 85) = 3.80$, $p = .055$, $\eta_p^2 = .04$. The main effect of feedback failed to reach significance, $F < 1.15$, as did the feedback x block interaction, $F(1, 85) = 2.83$, $p = .096$, $\eta_p^2 = .03$. The ANOVA on the percentage of conscious structural knowledge responses revealed no significant main effect of block, $F(1, 85) = 2.80$, $p = .098$, $\eta_p^2 = .03$, or feedback, $F < 1$. However there was a significant feedback x block interaction, $F(1, 85) = 4.01$, $p = .049$, $\eta_p^2 = .05$. The data were split by feedback group, revealing no significant change in the percentage of conscious structural knowledge responses within the no feedback group, $t < 1$, $dz = 0.05$; but a significant increase between experimental blocks within the feedback group, $t(46) = 2.40$, $p = .020$, $dz = 0.85$.

Table 1: *Percentage of trials per experimental block attributed to guess, unconscious and conscious structural knowledge attributions as a function of feedback condition. Standard errors appear in parentheses*

	Feedback		No feedback	
Structural knowledge	Block 1	Block 2	Block 1	Block 2
Guess	11 (2.41)	11 (2.79)	10 (1.63)	11 (1.82)
Unconscious	54 (3.38)	48 (3.58)	56 (3.66)	56 (3.88)
Conscious	35 (3.66)	41 (3.81)	34 (3.97)	33 (4.14)

Accuracy

Table 2: *Proportion of correct responses as a function of knowledge type, block and feedback. Standard errors appear in parentheses*

	Feedback		No feedback	
Structural knowledge	Block 1	Block 2	Block 1	Block 2
Guess	.56 (.07)	.56 (.04)	.68 (.04)	.56 (.06)
Unconscious	.69 (.02)	.69 (.03)	.75 (.03)	.63 (.03)
Conscious	.73 (.04)	.72 (.04)	.77 (.04)	.80 (.04)

A 2 x 2 x 2 (Structural knowledge type [conscious vs. unconscious] x Block [block 1 vs. block 2] x Feedback [feedback vs. no feedback]) mixed ANOVA was conducted on the proportion of correct responses ($N = 76$). (As only 43 participants used at least one random selection response, guesses were considered separately.) See Table 2 for descriptive statistics. Conscious structural knowledge responses ($M = .76$, $SE = .03$) outperformed unconscious structural knowledge responses ($M = .69$, $SE = .02$), $F(1, 74) = 7.53$, $p = .008$, $\eta_p^2 = .09$. There was no significant main effect of block, with similar overall performance in block 1 ($M = .74$, $SE = .02$) and block 2 ($M = .71$, $SE = .02$), $F < 1.80$, $\eta_p^2 = .02$. There was no significant main effect of feedback, $F < 1$, $\eta_p^2 = .01$. There were no significant two-way interactions, $F_s < 2.99$, $p_s > .088$. However, there was a significant knowledge type x block x feedback interaction, $F(1, 74) = 4.47$, $p = .036$, $\eta_p^2 = .06$.

Table 3: Block difference scores as a function of knowledge type and feedback. Standard errors appear in parentheses

	Feedback	No feedback
Unconscious	.00 (.03)	-.11 (.04)
Conscious	-.01 (.04)	.03 (.04)

Note: Positive values indicate an increase in accuracy in block 2.

In order to follow up this interaction, mean accuracy of block 1 was subtracted from mean accuracy of block 2 for both response types (henceforth ‘block difference’). Descriptive statistics are reported in Table 3 (positive values indicate an increase in accuracy across the experimental blocks). Independent samples t -tests were conducted, revealing a significant difference in the block difference of unconscious structural knowledge between the feedback and no feedback conditions, $t(74) = 2.48$, $p = .015$, $d = 0.56$. The same difference was not found for conscious structural knowledge responses, $t < 1$, $d = 0.17$. One sample t -tests were conducted against a value of zero (indicating no change in accuracy across experimental blocks). The block difference of unconscious structural knowledge responses without feedback

was significantly less than zero, $t(33) = 3.20$, $p = .003$, $d = 0.58$. The block difference of this response type with feedback was not detectibly different from zero, $t < 1$. For conscious structural knowledge responses, there was no detectible decrease in accuracy either under feedback or no feedback conditions, $ts < 1$. Thus, there was a relative decrease in accuracy of unconscious structural knowledge without feedback which was not the case when feedback was provided or for conscious structural knowledge irrespective of feedback.

Table 2 shows the accuracy of guesses. An orthogonal analysis revealed no significant effects, $Fs < 1.25$. However, it is of interest that the only condition under which random selection responses satisfied the guessing criterion – that is when above chance accuracy is displayed when both judgment and structural knowledge are unconscious (Dienes et al., 1995) – was in the first block without feedback, $t(26) = 3.71$, $p = .001$, $d = 0.72$ (all other $ts < 1.01$), a result predicted by the familiarity calibration process of Dienes and Scott (2010a).

Discrimination (d') and response criterion (C)

The contaminated familiarity and familiarity decay hypotheses were tested through signal detection measures, d' (indexing discrimination between grammatical and ungrammatical sequences) and C (indexing response criterion). Hit rates (HR) and false alarm rates (FAR) were calculated via the formulae $HR = (\text{hits} + 0.5)/(\text{hits} + \text{misses} + 1)$; and $FAR = (\text{false alarms} + 0.5)/(\text{false alarms} + \text{correct rejections} + 1)$, where the terms inside of the parentheses refer to frequencies. Note values of 1 or 0 are problematic for calculating d' and C (Snodgrass & Corwin, 1988, recommend the procedure of adding 0.5 to each cell as an arbitrary patch; but it can be justified from a Bayesian perspective as the implementation of a prior belief that d' is near zero, worth one observation for HR and one observation for FAR, i.e. it is a unit information prior for each, corresponding to the belief that with 95% probability HR lies between 5% and 95% and FAR the same; cf. Baguley, 2012.). See Table 4 for descriptive statistics. Only the analyses of d' and C are reported as the analyses on HR and FAR were consistent with findings for these measures or non-significant.

Table 4: *Hit rate (HR), false alarm rate (FAR), discrimination (d') and response criterion (C) for conscious and unconscious structural knowledge responses as a function of feedback and block. Standard errors appear in parentheses.*

Structural knowledge		HR	FAR	d'	C
Feedback					
Conscious	Block 1	.63 (.03)	.27 (.03)	1.18 (.17)	.14 (.06)
	Block 2	.64 (.04)	.30 (.03)	1.12 (.17)	.14 (.08)
Unconscious	Block 1	.63 (.03)	.31 (.03)	1.02 (.13)	.09 (.07)
	Block 2	.64 (.04)	.34 (.04)	0.89 (.15)	.03 (.07)
No feedback					
Conscious	Block 1	.71 (.04)	.32 (.04)	1.28 (.20)	-.05 (.08)
	Block 2	.71 (.05)	.28 (.04)	1.40 (.20)	.03 (.09)
Unconscious	Block 1	.68 (.04)	.27 (.03)	1.26 (.20)	.11 (.08)
	Block 2	.61 (.04)	.40 (.04)	0.75 (.17)	.03 (.09)

Note. Values of C reflect response criterion where positive values indicate a conservative response bias and negative values indicate a liberal bias.

Thus, d' and C were entered into separate 2 x 2 x 2 (Structural knowledge type [conscious vs. unconscious] x Block [block 1 vs. block 2] x Feedback [feedback vs. no feedback]) mixed ANOVAs ($Ns = 71$). Considering d' , there was a significant main effect of knowledge type, with conscious structural knowledge resulting in greater sensitivity ($M = 1.25$, $SE = .12$) than unconscious structural knowledge ($M = 0.98$, $SE = .09$), $F(1, 69) = 5.64$, $p = .020$, $\eta_p^2 = .08$. The main effect of block approached significance, with marginally greater sensitivity in block 1 ($M = 1.19$, $SE = .09$) than block 2 ($M = 1.04$, $SE = .10$), $F(1, 69) = 3.79$, $p = .056$, $\eta_p^2 = .05$. The main effect of feedback was non-significant ($F < 1$). The only two-way interaction to reach significance was knowledge type x block, $F(1, 69) = 4.29$, $p = .042$, $\eta_p^2 = .06$ (other $Fs < 1$). However, as the three-way interaction was marginally significant, $F(1, 69) = 2.81$, $p = .098$, $\eta_p^2 = .04$, the data were split by feedback group. Within the feedback group,

there was no partial two-way interaction between knowledge type and block, $F < 1$. However, within the no feedback group, there was a significant partial knowledge type x block interaction, $F(1, 29) = 4.89, p = .035, \eta_p^2 = .14$. There was a significant reduction in the sensitivity of unconscious structural knowledge responses between blocks 1 and 2, $t(36) = 2.71, p = .010$; the same was not true of conscious structural knowledge responses, $t < 1$.

In terms of C, the three-way ANOVA revealed no significant main effects or interactions, $F_s < 1.26, p_s > .267$. Thus, in the absence of feedback, the sensitivity of unconscious structural knowledge towards grammaticality was reduced; there was no evidence that the same was true for unconscious knowledge when feedback was provided, nor for conscious structural knowledge generally. A change in response criteria was not detected.

Next, Bayes factors were conducted to assess whether the accuracy and discrimination data for conscious structural knowledge and the response criterion data of unconscious structural knowledge reflect evidence for the null or merely insensitive evidence. Bayes factors require a plausible range of effect sizes to be specified for the given comparison and indicate a continuum of support of hypotheses where values less than 1/3 designate substantial evidence for the null; values over 3 can be considered substantial evidence for the experimental hypothesis; values around 1 indicate no substantial support either way and suggest insufficient sensitivity in the experimental design (Jeffreys, 1961; see Dienes 2008b, 2011, for discussions on the relative merits and drawbacks of Bayesian and Orthodox statistics).

Two Bayes factors were calculated for conscious structural knowledge; one for the proportion of correct responses and one for d' . The data were modelled as half normals, with a mode of 0 and SDs set to the mean estimate reductions between blocks for unconscious structural knowledge between no feedback and feedback groups for both accuracy (SD = .115) and sensitivity (SD = .374). The reduction in accuracy for conscious knowledge in the no feedback group was -.042 (SE of the difference = .055), yielding a Bayes factor of 0.27,

indicating substantial evidence for the null. The reduction in discrimination was $-.181$ (SE of the difference = $.236$), giving a Bayes factor of 0.34 , approaching substantial evidence for the null.

To calculate the change in C in the current study, the difference between blocks in the no feedback condition was subtracted from that of the feedback condition, giving a mean difference of $.027$ (SE of the difference = $.113$). Yonelinas and Levy (2002, Experiment 2) directly investigated reductions in recognition as a function of intermediate term delays (see Yonelinas, 2002, for review). Acceptance rates of targets and lures fell in parallel over an 8- and 32-item lag similar to the thirty trial blocks in the current study, giving a change in C estimated at $.36$. However, this is a likely underestimate in familiarity as all acceptance rates were included, thus an influence of recollection – thought resilient to intermediate term forgetting – cannot be ruled out. The change in C in the current study was therefore modelled as a half normal with a mode of 0 and SD of $.40$. This comparison yielded a Bayes factor of 0.33 , approaching strong evidence for the null. Note that considering the change in C between block 1 and block 2 in the no feedback group in isolation gives a mean difference of $-.077$ (SE of the difference = $.084$), yielding a Bayes factor of 0.12 indicating strong evidence for the null.

Discussion

The hypothesis that feedback would increase the availability of conscious structural knowledge was supported. Feedback led to an increase in the proportion of responses attributed to rules and recollection; thus, external feedback accelerates the process of deriving conscious structural knowledge. This is predicted by the Scott and Dienes (2010a) dual-process model of AGL. According to this model, conscious structural knowledge can be derived through the monitoring of unconscious structural knowledge responses (i.e.: a form of self-generated feedback). For example, participants may consciously realise never classifying a sequence containing a certain element as grammatical. Such sequences may hitherto have been attributed to intuition or familiarity but once the realisation has been made, they may attribute to rules or recollection

instead as their conviction of encountering (or not) a salient element from training increases (an element that may become salient because of feelings of (un)familiarity associated with it). The results presented here show that feedback accelerates this process of hypothesis testing. It is not surprising that this did not occur without feedback in the current study; it could simply be the case that sixty test sequences is not enough for this process to reveal itself under incidental learning. Furthermore, although this theory posits a general shift of increasing metacognition at test, any conscious structural knowledge which was thought unreliable by the participant leads back to a reliance on intuition or familiarity. Feedback allows the veracity of conscious structural knowledge to be independently verified and its use continued. Similar results are found from rule-search training instructions. For instance, Dienes and Scott (2005) found that instructing participants to search for rules in the training phase of AGL (thought to maximise explicit learning of the grammar) led to a 10% increase in conscious structural knowledge attributions and the current results show an increase of 6% of such attributions as a function of feedback under incidental learning (the same materials were used here as in the Dienes and Scott study). The key difference, however, is that rule-search instructions encourage explicit learning during learning whereas feedback encourages greater amounts of conscious structural knowledge to be derived at test from incidentally acquired knowledge. Additionally, the guessing criterion (Dienes et al., 1995) was only satisfied in the first block without feedback, suggesting that feedback accelerated the process of reliably estimating sequence familiarity compared to sequences encountered thus far (calibration), which extends Scott and Dienes' (2008) findings with confidence encouragement.

Without feedback, there was a relative decrease in the accuracy of unconscious structural knowledge, whereas the accuracy of conscious structural knowledge was relatively maintained throughout the test phase regardless of feedback. The source of inaccuracy in unconscious structural knowledge responses was a relative deficit in grammar sensitivity, and not a shift in response criterion; conversely, the feedback manipulation had little effect on conscious structural knowledge accuracy. Two contrasting explanations underlying the effect on

unconscious structural knowledge, contaminated familiarity and familiarity decay, are discussed.

Contaminated familiarity is anticipated by a theory that the feeling of familiarity toward a current sequence is dependent on the elements within all preceding exemplars. Here, participants implicitly learned (some of) the regularities of the to-be-rejected grammar at test and this contaminated familiarity was expressed through unconscious structural knowledge. When feedback was provided, encroaching familiarity with to-be-rejected sequences could be contextualised. Familiarity signals became confounded in the participant's mental state when feedback was absent, reducing discrimination (i.e.: the probability distributions relating to grammatical and ungrammatical sequences become drawn together in terms of their subjective familiarity; see also Higham et al., 2000). Sequences that the experimenter considers should result in a feeling of familiarity do not necessarily match those of the participant. Importantly, unconscious structural knowledge was not reduced to baseline levels in the absence of feedback. In fact, 63% of unconscious structural knowledge responses in the second block were correct and 65% performance is typical, thus accurate knowledge was still demonstrated despite a relative reduction in the quality of this knowledge (note that although there was an accuracy reduction *within* the no feedback group, the difference *between* groups was not substantial). Wan et al. (2008) discuss the possibility that multiple types of familiarity can be acquired in AGL (e.g.: Type A and Type B reflecting the respective grammars), positing that intentions can increase reliance on one type over the other. Feedback may work in a similar manner through alerting participants to encroaching familiarity from to-be-rejected sequences which allows participants to contextualise competing familiarity signals. Note that contextualisation is inconsistent with the Jacoby (1991) definition of familiarity as a memory process that occurs regardless of intent, but is in-line with the Dienes, Scott and Wan (2011) definition as a continuous indication of 'oldness' emerging from learning.

Conversely, the accuracy of conscious structural knowledge was maintained throughout, regardless of feedback (although the number of trials based on conscious structural

knowledge increased with feedback). This suggests the quality of conscious structural knowledge cannot easily be improved simply through providing feedback (evidence approached the null for discrimination and strongly supported the null for accuracy). If a participant uses inaccurate conscious knowledge (e.g.: a false recollection, mistaken reconstruction or a derived rule which was incorrect), they may erroneously and consistently endorse sequences with that element as grammatical if they are not alerted to which of their rules is incorrect, which may also account for the lack of a detectable feedback effect on confidence (Dienes, Kurz, Bernhaupt & Perner, 1997; Dienes & Scott, 2005; Reber, 1989). Further, contaminated familiarity was not reflected in recollection or rule-based conscious knowledge which go beyond familiarity. When structural knowledge is conscious, the decision is a binary one (perhaps based on a subjectively defined decision criterion), and there is relatively little noise in the decision making process compared to using continuous familiarity signals to guide responding. The predicted dissociation between knowledge types supports the structural knowledge attribution methodology.

The recognition memory literature states that a familiarity signal decays under the medium term (as in an experimental setting) but recollection is largely maintained (see Yonelinas, 2002, for review), which predicts a shift toward conservative responding through a reduction in overall endorsement as opposed to a reduction in discrimination. However, the data approached strong evidence for the null comparing the feedback groups (and substantial evidence considering the no feedback group in isolation), thus the contaminated familiarity explanation is a better fit of the data. However, response criterion and discrimination are not mutually exclusive and future research could investigate changes in these measures using alternatives to the classic AGL protocol (see e.g., Chen et al. 2011; Jiang et al., 2012; Neil & Higham, in press; Rebuschat & Williams, 2009; Rohmeier, Fu & Dienes, in press).

The results presented here potentially contradict those of Mathews et al. (1989), who found feedback increased accuracy rather than maintain it. However, the current study used only one session of sixty trials, which is not comparable with the 800 trials over multiple sessions

used by Mathews et al. Rather, the setting was similar to the majority of AGL studies (including subjective measures of awareness) and single session studies are certainly vital to researchers in the field by virtue of their practicality. It is plausible that repeating the current study with a larger number of trials or testing sessions would show feedback increases, rather than merely maintains the accuracy of unconscious structural knowledge which would be a worthwhile area for future research, particularly if analogies wish to be drawn between AGL and natural language learning. Achieving the highest levels of expertise in language learning requires both immersion in that language environment as well as formal training in proper use of the language such as spelling, language use, appropriate conversational use and so on (Ellis & Laporte, 1997).

Domangue et al. (2004) and Sallas et al. (2007) investigated the role of different AGL training techniques on participants' ability to generate grammatical sequences. Incidental learning resulted in quick but relatively inaccurate responding; model-based learning resulted in slower but more accurate responding; and model-based learning with additional structural information resulted in rapid responding with no speed-accuracy trade-off. This kind of synergy between bottom-up exemplar training and top-down model-based based learning may most accurately reflect learning in natural settings (see also Kovic et al., 2008). Additionally, Whittlesea and Wright (1997; see also Whittlesea & Dorken, 1993; Wright & Whittlesea, 1998) contend that explicit and implicit learning do not proceed by fundamentally different principles but the acquisition and application of knowledge will depend on how the participant decides to respond to the current context. Replicating these studies with respect to structural knowledge attributions would reveal the relative contributions of conscious and unconscious structural knowledge to performance in the learning of structured regularities under different forms of training and could potentially provide a model of how structural knowledge develops over longer time periods than in the current study.

AGL provides a simplified analogy of how implicit learning can lead to conscious and unconscious knowledge in everyday contexts. Clearly, natural language learning is a much

richer learning experience. Cleeremans (2006) states that repeated practice leads to higher quality representations and Mathews (1997) argues that practice and greater exposure can lead to expert levels of unconscious knowledge. Yet, feedback often accompanies performance based on the products of implicit learning in everyday settings, which is often not the case in laboratory studies. Nonetheless, the notion that feedback supports unconscious knowledge and leads to the development of conscious structural knowledge was borne out in a standard AGL task. Without feedback, unconscious structural knowledge shows a relative deterioration in the gradually contaminated familiarity signal (but note that reasonable accuracy was found for this knowledge type). On the other hand, conscious structural knowledge accuracy was not detectibly affected by feedback, demonstrating a theoretically expected difference between the natural kinds of conscious and unconscious structural knowledge (cf. Dienes, 2012).

Chapter V

Conscious and unconscious thought in 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 metacognitive 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.

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 & K. van den Bos, 2010, 2011; Ham, K. 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 et al. (2011) argued that as these decision making tasks are complex, unconscious thought leads to superior decision making quality than conscious thought. According 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 and 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, González -Vallejo, Bellezza & Phillips, 2009; Payne, Samper, Bettman & Luce, 2009; Queen & Hess, 2010; Thorsteinson & Withrow, 2009; Waroquier, Marchiori, Klein & Cleeremans, 2009, 2010; 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 Evans, 2008, 2010; Dienes, 2008a, 2012; Glöckner & Wittman, 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 González-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, 2010b; Persuad, McLeod & Cowey, 2007; Scott & Dienes, 2008, 2010b, 2010c, 2010d; 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.: Dienes & Scott, 2005; Scott & Dienes, 2008, 2010a, 2010b, 2010c, 2010d; Wan, Dienes & Fu, 2008; Chen et al., 2011; Guo et al., 2011; Rebuschat & Williams, 2009).

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, Lewes and Cantor (1980) argued the negative effect of rule search depended on grammar complexity (reminiscent of Dijksterhuis’ claims about unconscious versus conscious thought; see also E. van den Bos and 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 and Dienes 2008, 2010a) 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 & K. 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 (2010c), 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 five minute period in which participants were instructed to think about the rules of training items just studied or a five minute 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. 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.

Method

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 E. 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 Figure 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 E. 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 five minutes about the rules governing the structure of the strings (rule discovery) or were asked to complete mathematical problems for five minutes (distraction).

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.

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 the appendix. 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 x 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.

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 five seconds. 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 five minutes 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 five minutes (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:* Your 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.

Results

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: *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 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).

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 a significant difference between rule discovery and immediate conditions, $p = .002$. 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.

Intermediate phase and classification accuracy

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)

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 metaknowledge 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 responses² ($n = 130$) was significant (see Table 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, $t(84) = 2.39, p = .020, d = 0.51$, and marginally higher accuracy than immediate progression, $t(85) = 1.77, p = .080, d = 0.38$. The difference between immediate progression and rule-discovery was not significant, $t(85) = 0.60, p = .554, 95\% \text{ CI } [-.06, .11], d = 0.13$.² Furthermore, distraction resulted in accuracy significantly above the chance value of 50%, $t(42) = 3.63, p = .001, d = 0.78$, satisfying the guessing criterion of unconscious knowledge (Dienes et al., 1995). This was not true of immediate progression, $t(43) = 1.26, p = .214, d = 0.30$, nor rule discovery, $t(42) = 0.46, p = .646, d = 0.01$.

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,

² The results on accuracy for guess responses were augmented with a signal detection analysis; specifically d' and C . The one-way ANOVA on d' revealed no significant main effects (Distraction $M = .34, SE = .12$; Rule discovery $M = .11, SE = .09$; Immediate progression $M = .24, SE = .11$), $F(1, 113) = 1.20, p = .305$. Similarly, the ANOVA on C revealed no significant effects (Distraction $M = .50, SE = .09$; Rule discovery $M = .40, SE = .08$; Immediate progression $M = .37, SE = .09$), $F < 1$. It is unclear whether the advantage after distraction is due to a change in discrimination or response bias.

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 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 E. 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 and Newell and Rakow (2011) for another Bayesian analysis of UTT effects.)

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 metaknowledge 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 metacognitive 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 metacognitive 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 & K. 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, 2010b). 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’ metaknowledge. 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 on-going 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, 2010a, for discussions of how knowledge may become conscious in AGL).

Chapter VI

Drawing on the contents of memory: Verbal recoding leads to a conservative shift in recollection

Abstract

The verbal overshadowing (VO) effect was investigated in the context of the remember/know paradigm. Several competing theories of VO exist and this chapter focuses on the antecedents and boundaries of the conservative shift interpretation, where the engagement of verbal processing of visual materials is thought to result in more conservative recognition judgments. Evidence for this interpretation is mixed. Thus, a novel paradigm was used, designed to be more sensitive to the effect. Participants were shown arrays of easy-to-name or hard-to-name shapes and either copied or described (verbally recoded) the elements within those arrays. At test, they decided whether arrays were old or new, and gave a remember, know or guess response following an old decision. There was no difference detected in the overall number of endorsements between encoding styles but verbalisation led to a shift from remembering to guessing, indicating participants were more conservative in a feeling of recognition. Furthermore, there was a conservative shift within remember responses. Results suggest the conservative shift can be elicited as a product of verbal recoding and the conservative shift is most heavily implicated in recollection.

Introduction

The relationship between verbalisation and recognition performance is multifaceted. *Verbal overshadowing* (VO; Schooler & Engstler-Schooler, 1990) has become an intriguing research topic over the past twenty years. VO is said to occur when verbalising about a task is deleterious to performance. In typical studies eliciting the effect, participants are required to perform a task and some are asked to engage in verbal processing while others are not. After verbalisation, performance has been shown to be impaired in domains such as face recognition (Brown & Lloyd-Jones, 2002, 2003); visual imagery and mental rotation (Brandimonte & Collina, 2008); decision making (Wilson & Schooler, 1991) and problem solving (Schooler, Ohlsson & Brooks, 1993). Additionally, the VO effect has been found for many kinds of perceptual stimuli including faces (Brown & Lloyd-Jones, 2002, 2003), shapes (Brandimonte, Hitch & Bishop, 1992a, 1992b, 1992c), colours (Brandimonte, Schooler & Gabbino, 1997), recognition of mushrooms (Melcher & Schooler, 2004) and in non-visual modalities where it has been shown in voices (Perfect, Hunt & Harris, 2002), taste recognition of wines (Melcher & Schooler, 1996), and jam preferences (Wilson & Schooler, 1991).

There are three primary accounts of VO; however no one explanation dominates and different mechanisms may be responsible for the effect depending on context (see Chin and Schooler, 2008; Lloyd-Jones, Brandimonte & Bäuml, 2008, for review). The *content* account centres on recoding a visual trace with a verbal memory where the original memory was optimal for successful performance; i.e.: verbal representations interfere with crucial non-verbal representations (Schooler & Engstler-Schooler, 1990). Secondly, the *processing shift* account focuses on the interference between verbal and non-verbal mental operations. This theory posits that verbalisation encourages local processing of the individual features constituting a stimulus (featural processing) at the expense of globally processing the entire display, resulting in impairment due to the adoption of non-optimal strategies (for evidence see e.g.: Brown & Lloyd-Jones, 2002, 2003; Dodson, Johnson & Schooler, 1997; Fallshore & Schooler, 1995; see Schooler, 2002, for a review of this account). Thirdly, the *criterion shift* account, introduced by

Clare and Lewandowsky (2004), posits that verbalisation alters recognition criteria. In their study, participants witnessed an event, some of whom described the perpetrator after the incident before identifying the perpetrator from a line-up. Verbalisers showed a greater reluctance to identify the perpetrator than non-verbalisers. However, when the actual perpetrator was not present in the line-up, non-verbalisers were more willing to incorrectly identify another person (a 'false alarm'). They concluded that verbalisation leads to a criterion shift towards more conservative recognition judgments, without necessarily affecting overall accuracy levels (see also Meissner, 2002; Sauerland, Holub & Sporer, 2008; Winkielman & Schwartz, 2001). The antecedents of this recognition shift are currently not well understood and it is not clear whether conservative responding is a manifestation of other proposed mechanisms or a quite separate theory as verbalisation often results in reduced discrimination ability rather than a general reluctance to endorse targets as previously encountered. The aim of this paper is to distinguish recognition discrimination ability from response criteria as a function of verbalisation and establish boundaries where conservative responding can be expected.

Many VO studies involve verbalisation manipulations before a single stimulus recognition judgment based upon the original procedure by Schooler and Engstler-Schooler (1990). This procedure has led to reliable overshadowing effects (e.g.: Dodson et al., 1997; Fallshore & Schooler, 1995; Ryan & Schooler, 1998), and provided evidence of more conservative responding after engagement in verbal processes (Clare and Lewandowsky, 2004; Sauerland et al., 2008). However, in multiple stimulus recognition paradigms, verbalisation often produces deficits in discrimination ability, rather than criterion shifts. The *post-stimulus encoding* method involves exposure to a number of learning stimuli before the description of a single item from memory followed by multiple test stimuli. According to their signal detection analysis (requiring multiple test stimuli), Brown and Lloyd-Jones (2002, 2003) report reduced discrimination after verbalisation using this method without a change in criterion interpreted as a processing shift from global to local orientation.

Signal detection, as applied to recognition, is a method used to assess discrimination ability between old and new test stimuli (indexed by the d' statistic) and to determine the criteria by which stimuli are accepted as 'old' (indexed by the C statistic). Memory retrieval processes compare a test item with what is stored in memory and the degree of match between the test item and memory contents is characterised by memory strength (generated by factors such as similarity, contextual information, spatiotemporal information or familiarity signals constituting the degree of evidence that the item has been previously encountered). Old/new decisions are driven by strength as items eliciting greater strength have a greater weight of evidence of being previously encountered. The value of d' corresponds to the difference in standardised mean memory strength between old and new items; as such the greater the value of d' , the greater discrimination between old and new test items. The point on the memory strength axis at which an 'old' decision is made is the response criterion, C , and this can be flexible. A liberal criterion is shown when items are classified as old on the basis of relatively low memory strength which increases the rate of both hits (correct endorsement) and false alarms (erroneous endorsement) as both more targets and lures are accepted as old. Conversely, a conservative criterion is shown when C reflects relatively high memory strength as both the number of hits and false alarms is reduced; increasingly conservative responding is indicated as C increases beyond zero (e.g.: Dunn, 2004; Snodgrass & Corwin, 1988; Wixted and Mickes, 2010). Signal detection methods are thus particularly suited to the investigation of response criteria in recognition. However, d' and C are independent, thus previous failures to find changes in C (Brown & Lloyd-Jones, 2002, 2003, 2005, 2006; Lloyd-Jones & Brown, 2008; Nakabayashi, Burton, Brandimonte & Lloyd-Jones, 2012) – as would be predicted by criterion shift – could reflect insensitivity in the post-stimulus encoding design.

One aspect of VO that has not received much empirical attention is how different experiences of recognition may be affected by verbalisation. Dual-process theories of recognition memory broadly state there are two ways in which recognition can occur: recollection and familiarity. Recollection is viewed as controlled retrieval of a previous learning

episode in which one consciously remembers encountering the information (e.g.: with spatiotemporal detail). Familiarity is conceptualised as an automatic process giving rise to a feeling of previously encountering the information but without specific conscious recollection of that learning episode (Tulving, 1985; Jacoby, 1991). A commonly used method instantiating this theory is the remember/know paradigm (R/K; see e.g.: Diana, Reder, Arndt & Park, 2006; Gardiner, Ramponi and Richardson-Klavehn, 2002; Wixted & Mickes, 2010; Yonelinas, 2002, for reviews), data from which are often interpreted within a signal detection framework. Typically in R/K studies, participants are shown word lists before being required to discriminate between old target words that were presented previously and new lures. Source judgements are given when stimuli are classified as old: either remember (R) – indicating recollection; know (K) – indicating a feeling of familiarity without conscious recollection; and occasionally guess (G) – indicating no feeling of familiarity despite the item being accepted as old. Wixted and Mickes (2010) present a continuous dual-process threshold-based model of recognition judgments. According to this theory, the R criterion is placed on a recollection axis and the K criterion on a separate familiarity axis. When an item with aggregated memory strength satisfies the ‘old’ criterion, recollection is queried (and R is reported if a criterion is satisfied). If not enough recollection has occurred, familiarity is interrogated and K reported if satisfied; otherwise a G response is given, which indicates the memory strength of an item falls close to the old/new boundary. However, most VO studies omit these reports meaning there is little research directly investigating different recognition strategies adopted by verbalisers versus non-verbalisers. Do verbalisers ‘remember’, ‘know’, or ‘guess’, and how are these processes affected by verbalisation? This issue has begun to be addressed by Lloyd-Jones and Brown (2008). They found that post-stimulus encoding verbalisation reduced R discrimination, with some evidence of a liberal shift over a small number of test items immediately following verbalisation, which is not anticipated by the criterion shift account (see Brown & Lloyd-Jones, 2006, for verbal facilitation effects and their relationship with recollection and familiarity). Furthermore, Nakabayashi, et al. (2012) failed to find evidence of a recognition criterion shift in their multiple post-stimulus encoding paradigm (see also Brown & Lloyd-Jones, 2002, 2003).

Thus far, the evidence for criterion shifts due to verbalisation is mixed. However, failures to find the effect using the post-stimulus encoding method may mean that processing orientation does not affect recognition criteria but this has little to say on the representational content produced by verbalisation. The content account of VO is predicated on the notion of *recoding interference* (Meissner, Brigham & Kelley, 2001; Brandimonte & Collina, 2008; Schooler & Engstler-Schooler, 1990), which has long been known for disruptive effects upon recognition performance (e.g.: Bahrack & Bahrack, 1971; Bahrack & Boucher, 1969; Daniel, 1972; Nelson & Brooks, 1973). That is, when stimuli are processed via a different modality from presentation (e.g. recoding visual materials verbally), performance can suffer as acquired representational content is not optimised for recognition and Nakabayashi et al. (2012) and Huff and Schwan (2008) speculate that VO can arise due to the competition between perceptual and semantic/conceptual memories when the former is crucial to optimal performance. Recoding interference would place these in opposition. However, a control method is required that maintains perceptual expertise that would only otherwise be degraded by verbal engagement. One candidate is reproducing the stimuli through copying: drawing should retain the perceptual features of a visual stimulus at optimal levels (e.g.: Kozbelt, 2001; Seeley & Kozbelt, 2008) relative to descriptions. See Walker, Blake and Bremner (2008) and Walker, Kennedy & Berridge (2011) for drawing versus verbalisation manipulations in visual memory research and their relation to VO. Note that *automatic* verbal recoding of pictorial stimuli does not occur (Boldini, Russo, Punia & Avons, 2007; Mintzer & Snodgrass, 1999; Weldon & Coyote, 1996), making copying an ideal control to minimise verbal interference in a VO task. See also Paivio and Csapo (1973) who equal levels of recall after participants were instructed to describe or draw pictorial stimuli. However, this does not allow determination of response recognition criteria (see Dewhurst & Conway, 1994; Gardiner, Gregg, Mashru & Thaman, 2001; Mintzer & Snodgrass, 1999; Stenberg, Radeborg & Hedman, 1995, for work on recognition memory using pictorial stimuli).

Clare and Lewandowsky (2004) state that “research to date does not explain why the recognition criterion is raised following verbalisation” (p. 754). However, they speculate that is perceived task difficulty and the monitoring of one’s performance (i.e.: description adequacy) are implicated in producing conservative responding (see also Winkielman & Schwartz, 2001). That is, the less amenable a stimulus is to verbalisation, the greater the shift toward conservative responding should be. To test this hypothesis a direct comparison can be made between shapes with common names in English (henceforth ‘regular’) or no common name (henceforth ‘irregular’). Regular shapes are easily labelled, thus subjective description adequacy should be greater than for irregular shapes which are not easily labelled. An alternative prediction can be derived from the work of Nakabayashi et al. (2012). They found that prior familiarity with test materials benefited recognition independently of verbalisation manipulations at encoding. Thus, it could be the case that verbalising materials with common names (thus current encoding would be supported by prior experience) increases discrimination, compared to verbalising irregular arrays which would be novel. Thus the criterion shift theory predicts more conservative responding – without a change in discrimination ability – for irregular materials due to verbalisation; the prior familiarity hypothesis predicts a discrimination advantage for regular over irregular stimuli irrespective of verbalisation (note that discrimination and criterion are independent and both could occur).

The evidence for conservative recognition as a product of verbalisation is mixed; the goal of the current study was to investigate response criteria in recognition as a function of verbal processing using an encoding manipulation designed to maximise differences in verbal engagement. Clare and Lewandowsky (2004) advocate investigating the relationship between subjective experience and criterion placement, thus the current design incorporates R/K/G methods. Chin and Schooler (2008) state that criterion shift studies should “enable the separate determination of criterion and discrimination measures... [which] should be done concurrently with assessments of global processing shifts” (p. 410). In order to meet these recommendations, multiple element shape arrays (regular and irregular) were constructed for use as learning and

test stimuli. Picture discrimination performance is generally close to ceiling with few false alarms (e.g. Stenberg et al., 1995). Arrays require items to be matched on the basis of multiple constituent elements. This challenging recognition task is likely to increase false alarms as targets and lures would be share superficial similarity (see method section), and a reasonable false alarm rate is necessary for satisfactory response criterion estimates. Changes in local/global processing (Schooler, 2002) were also controlled for as participants were instructed to process each element in the learning arrays serially, that is each array should be processed locally regardless of encoding strategy before a global match at test.

Two predictions can be derived regarding the distribution of response types. Verbalisation may result in fewer ‘old’ responses as participants would be more likely to reject stimuli as new (i.e.: less willing to endorse stimuli falling close to the old/new criterion). However, a shift from remembering to guessing may also be expected if the threshold for giving an R or K response is not met (Wixted & Mickes, 2010); that is the criterion for a *feeling* of oldness toward test stimuli is not satisfied. Both of these predictions are concerned with criterion effects but the former focuses on absolute recognition and the latter on recognition types. Furthermore, the subjective difficulty interpretation of the conservative shift predicts a pronounced rising of recognition criteria for irregular stimuli whereas the prior familiarity hypothesis predicts a discrimination advantage for regular arrays independently of encoding. These hypotheses will be tested, which should allow for boundaries upon conservative responding to be established.

Method

Design and Participants

Eighty-four native English speakers (86% female) were recruited at the University of Sussex and participated in exchange for course credit (three further participants were excluded as they were non-native speakers). Ages ranged from 18 to 49 years. A mixed factorial design was used.

The independent measures variables were encoding style (describe vs. copy) and array type (regular vs. irregular). The repeated measures variable was response type (new, remember, know or guess). Such a design was considered appropriate to discount potential carryover effects resulting from verbalisation (Brown & Lloyd-Jones, 2002, 2003; Lloyd-Jones & Brown, 2008).

Materials

Seven familiar regular shapes with common names in English (cross, circle, triangle, diamond/rhombus, square, star, hexagon) and seven irregular shapes, with no common name in English, were produced as black and white line drawings (see appendix). Each shape from both sets was assigned an arbitrary number from 1 – 7. A random number generator was used to select arrays of four elements which were displayed on a white background (earlier pilot work suggested this number would avoid floor/ceiling effects and is also in-line with proposed constraints on visual working memory, e.g.: Vogel, Woodman & Luck, 2001). The only constraint on array generation was that the same shape could not appear consecutively more than twice. This ensured that relationships between elements within each array type were kept constant. Each shape in the array had a length and width of approximately 2.5 cm. All arrays were displayed in a horizontal line with a spacing of 4 cm between the midpoint of each shape. Forty-two regular and irregular arrays of shapes were generated in total. These were combined into two lists of twenty-one arrays; half of which would act as targets and half as lures (similar to the number of old test items used by Lloyd-Jones & Brown, 2008). The lists were counterbalanced so target items for half of the participants were used as lures for the other half and vice versa. The order of arrays within each list was randomised between participants.

Procedure

Participants were tested individually at a computer running EPrime 2.0 software. During the learning phase, each array from the assigned list was shown sequentially. Arrays were shown for ten seconds which the participant was instructed to concentrate on before the screen went blank for ten seconds. During this time participants were required to either copy by drawing or describe in words (according to encoding condition) the shapes in the array they had just seen in order on a piece of paper provided. After the learning phase they were given a five minute unrelated mathematics distraction task (none completed the task in the five given minutes).

One-step R/K procedures (R, K, G or 'new') are associated with a more liberal response criterion than two-step procedures (Bruno & Rutherford, 2010; Hicks & Marsh, 1999), therefore a two-step test procedure (first the old/new decision and if selecting old, then providing the R, K or G response) was used as demonstrating a conservative shift would be more convincing using this methodology. At the beginning of the test phase, participants were informed that they would see another series of shape arrays and that they were required to discriminate between exact arrays that had been presented previously and those that had not (they were told that 50% of the arrays had been previously presented to avoid floor or ceiling effects). If they thought the array was old, they were instructed to press 1 on the keyboard. If they thought it was new, they were instructed to press 0. The following instructions (adapted from Dewhurst & Conway, 1994) for remember, know and guess instructions were given: "If you remember seeing the array earlier, press R for the 'remember' response. This means, for example, you remember specific details about the array such as some aspect of its physical appearance or thoughts or feelings you had when you saw it. If the array feels familiar, but you cannot recall its actual occurrence earlier, press K for the 'just know' response. If you cannot decide whether or not the array was presented earlier but guessed it was, press G for 'guess' response (this is the equivalent of flipping a coin to make your old/new choice)". After classifying all 42 arrays, participants were asked to rate the difficulty of the encoding task. They rated on a scale from 0 – 6 (very easy –

very difficult) how difficult it was to copy/describe [depending on encoding condition] the shapes at the beginning of the experiment.

Results

Response types

Table 1: Mean number of trials judged as ‘old’ overall and R, K and G responses separately as a function of array type and response. Standard errors appear in parentheses

	Describe		Copy	
	Regular	Irregular	Regular	Irregular
Overall	20.60 (0.92)	21.33 (0.90)	20.75 (0.92)	22.45 (0.86)
Remember	7.95 (1.13)	8.76 (1.10)	10.05 (1.13)	11.57 (1.05)
Know	6.85 (0.92)	7.71 (0.90)	7.70 (0.92)	6.39 (0.86)
Guess	5.80 (0.81)	4.86 (0.79)	3.00 (0.81)	4.49 (0.79)

The following analyses all used 2 (Encoding style: description vs. copy) x 2 (Array type: regular vs. irregular) independent ANOVAs. Firstly, the number of R, K and G responses given when participants gave an ‘old’ response were considered ($N = 84$). See Table 1 for descriptive statistics. There was a significant main effect of encoding on R responses, with fewer ‘old’ trials given an R response after description ($M = 8.36$, $SE = 0.79$) than copying ($M = 10.81$, $SE = 0.77$), $F(1, 80) = 4.95$, $p = .029$, $\eta_p^2 = .06$. There was no significant main effect of array type, nor an encoding x array type interaction, $F_s < 1.12$. No significant main effects or interactions were found acting on K responses, $F_s < 1.46$. In terms of G responses, there was a significant main effect of encoding with a greater number of trials identified as old being given a G response after description ($M = 5.32$, $SE = 0.56$) than copying ($M = 3.74$, $SE = 0.55$), $F(1, 80) = 4.07$, $p = .047$, $\eta_p^2 = .05$. There was no significant main effect of array type, nor an interaction,

$F_s < 2.36$. This pattern suggests that fewer old responses were subsequently given an R response after verbalisation (regardless of array type) with a shift towards guessing.

Discrimination and response criteria

Table 2: *Hit rate (HR), false alarm rate (FAR), discrimination (d') and response criterion (C) for recognition, R responses and K responses as a function of encoding style and array type. Standard errors appear in parenthesis*

		Describe		Copy	
		Regular	Irregular	Regular	Irregular
Recognition	d'	.49 (.09)	.23 (.09)	.39 (.09)	.29 (.08)
	C	0.03 (.06)	-0.02 (.06)	0.02 (.06)	-0.08 (.05)
Remember	HR	.26 (.03)	.26 (.03)	.32 (.03)	.33 (.03)
	FAR	.19 (.03)	.18 (.03)	.21 (.03)	.27 (.03)
	d'	.27 (.10)	.31 (.09)	.37 (.09)	.20 (.09)
	C	0.86 (.09)	0.84 (.08)	0.69 (.09)	0.56 (.09)
Know	HR	.23 (.03)	.21 (.02)	.25 (.03)	.22 (.02)
	FAR	.13 (.02)	.18 (.03)	.19 (.03)	.14 (.03)
	d'	.42 (.12)	.16 (.11)	.16 (.12)	.36 (.11)
	C	1.00 (.80)	0.92 (.80)	0.89 (.09)	1.03 (.80)

Note: Values of C above 0 indicate a conservative bias. Values below 0 indicate a liberal bias.

Firstly, overall discrimination and response criterion measures (R, K and G responses) are reported before separate consideration of response types. Hit or false alarm rates with a value of 1 or 0 are problematic for calculating d' and C, therefore the data were transformed by adding a constant of 0.5 to each frequency and dividing by $N + 1$ where N equals the number of old/new trials (Snodgrass & Corwin, 1988). Descriptive statistics are reported in Table 2. The

reported analyses are limited to d' and C unless stated otherwise as the analyses on hit and false alarm rates were consistent with these measures or non-significant. C is reported for overall recognition, inclusive of guessing, familiarity and recollection, and separately for R responses (Yonelinas, 2002) and K responses (Wixted & Mickes, 2010); d' is reported for overall recognition, R and K responses. As sufficient discrimination between old and new trials (i.e. d' greater than zero) was not demonstrated for G responses overall ($M = -0.05$, $SE = .05$), $t < 1$, they were not entered into an orthogonal analysis. See Gardiner, Ramponi and Richardson-Klavehn, (1999, 2002) for discussion on how G responses can reflect noise in discrimination data.

For overall recognition ($N = 84$), the ANOVA on d' revealed a significant main effect of array type, with better discrimination for regular ($M = .44$, $SE = .06$) than irregular arrays ($M = .26$, $SE = .06$), $F(1, 80) = 4.79$, $p = .031$, $\eta_p^2 = .06$. There was no significant main effect of encoding style, nor a significant interaction, $F_s < 1$. The analysis on C revealed no significant main effects, nor an interaction, $F_s < 1.94$. Thus, participants showed better discrimination for regular arrays but encoding style did not detectably influence discrimination but response criterion was not detectably influenced by these factors.

Considering R responses ($N = 80$), there were no significant main effects or interactions acting on d' , $F_s \leq 1.34$. However, the ANOVA on C ($N = 80$) revealed significantly more conservative responding in the description ($M = .85$, $SE = .06$) than copying condition ($M = .63$, $SE = .06$), $F(1, 76) = 7.41$, $p = .008$, $\eta_p^2 = .09$. The main effect of array type was non-significant, as was the interaction, $F_s < 1$. Thus, there was no evidence of a shift in discrimination acting on recollection; but rather a criterion shift irrespective of array type.

In terms of K responses ($N = 80$), there was a significant array x encoding interaction on the false alarm rate, $F(1, 76) = 5.51$, $p = .022$, $\eta_p^2 = .07$, however this did not quite translate into a significant interaction on d' , $F(1, 76) = 3.67$, $p = .059$. Furthermore, there were no detectable main effects nor an interaction acting on C , $F_s \leq 1.69$.

Subjective Difficulty

Table 3: *Subjective difficulty ratings where 0 represents ‘very easy’ and 6 ‘very difficult’. Standard errors appear in parentheses.*

	Regular	Irregular
Describe	2.20 (0.30)	4.57 (0.29)
Copy	2.70 (0.30)	4.91 (0.28)

Table 3 shows the descriptive statistics for the subjective difficulty measure, where 0 represents ‘very easy’ and 6 ‘very difficult’. A 2 (Array type) x 2 (Encoding strategy) independent ANOVA was conducted on difficulty ratings ($N = 84$). There was a significant main effect of array type. Irregular arrays were rated as more difficult ($M = 4.74$, $SE = 0.20$) than regular arrays ($M = 2.45$, $SE = 0.21$), $F(1, 80) = 62.68$, $p < .001$, $\eta_p^2 = .44$. The effect of encoding strategy was not significant, with copying ($M = 3.81$, $SE = 0.20$) and describing ($M = 3.39$, $SE = 0.21$) receiving similar ratings, $F(1, 80) = 1.85$, $p = .150$, $\eta_p^2 = .03$. There was no significant interaction between the independent variables, $F < 1$. Although participants found the irregular arrays to be generally the more challenging stimulus type, there was no detectable difference in the perceived difficulty of the encoding styles.

Discussion

The principle aim of this experiment was to investigate antecedents and boundaries of the conservative criterion shift in recognition judgments due to verbalisation in a well-established paradigm (R/K) with a novel encoding manipulation. Participants were shown either easy-to-name regular arrays of shapes or difficult-to-name irregular arrays and either described or copied the elements in the arrays before matching at test. Verbalisation led to approximately 21

trials overall judged as ‘old’ and copying led to approximately 22 judged ‘old’. However, describing the arrays led to a shift from ‘remember’ to ‘guess’ judgments. This indicates the threshold for giving a familiarity or recollection response was not reached, which is indicative of a conservative shift in a *feeling* of oldness to test stimuli, or subjective experience of recognition (Gardiner et al., 2002; Wixted & Mickes, 2010)³. Thus, fewer responses accompanied with a feeling of oldness were made following verbalisation. Specifically within R responses, verbalisation participants required more subjective evidence from a test item to endorse it as old as their threshold was raised, perhaps through the overshadowing of perceptual information (this perceptual information would be superficial in nature as both hits and false alarms reduced in parallel; i.e. the rates of both accurate and erroneous recognition). Within R responses, it is important to note that changes in C could also represent a shift in the underlying evidence distributions. Instead of participants demanding more evidence from each test stimulus, the evidence distributions between encoding groups could have differed. Specifically, the general amount of evidence supporting recognition following verbalisation would be lower. In this scenario, the psychological criterion between groups would be constant but the evidence for both targets and lures in the copy group would be greater (and equidistant, as shown through the lack of a detected impact on d'). These possibilities, a criterion shift or evidence shift, agree on the behavioural consequences that fewer stimuli would be endorsed as old following verbalisation.

This pattern suggests criterion placement was affected rather than simply an unwillingness to endorse test stimuli. See Ardnt & Hirshman (1998); Rajaram, (1996, 1998); and Roediger & Gallo (2005) for articles on the relationship between stimulus similarity and

³ Note that there was no detectable change in response criterion for overall recognition. In order to determine whether this result reflected evidence for the null or merely insensitivity in the design, a Bayes factor was calculated where values less than 1/3 can be considered strong evidence for the null and values around 1 as insensitive evidence. The data were modelled as a half normal with a mode of 0 and the SD set to the mean difference between encoding groups found for R responses (.226). The same difference for recognition was .038 (SE of the difference = .056), giving a Bayes factor of 0.44. The data are largely insensitive and do not yet provide strong evidence for the null (see Dienes, 2008, 2011, for discussion on the use of Bayes factors and continuous degrees of support for hypotheses).

recognition processes; Mintzer & Snodgrass (1999) and Stenberg, Radeborg & Hedman (1995) for criterion effects in pictorial vs. word stimuli.

These results add boundaries on the conservative shift theory (Clare and Lewandowsky, 2004); verbalisation and copying participants endorsed roughly the same number of test arrays overall but verbalisation participants shifted from recollection to guessing and were more conservative in that recollection. The failure to find this effect in previous studies (e.g.: Brown & Lloyd-Jones, 2002, 2003, 2005, 2006; Nakabayashi et al., 2012) is not surprising as typical VO studies invoke overshadowing through post-stimulus encoding and do not make the distinction between recollection, familiarity and guessing (cf. Lloyd-Jones & Brown, 2008). The inclusion of R/K/G methods gave the experimental design sufficient sensitivity to detect the effect. This result is thus the virtue of the manipulation; the approach used here shows its merit through yielding results in line with theory while adding boundaries to where the conservative shift effect may be observed. Non-veridical encoding resulted in fewer recollections and raised the threshold within recollection, evoking a criterion shift as a *product* of encoding strategy (cf. Chin & Schooler, 2008).

Conservative responding was most heavily implicated in recollection and did not simply (detectibly) involve less willingness to endorse test stimuli *per se*. The findings from subjective difficulty support this conclusion. One proposed mechanism underlying the conservative shift theory as delineated by Clare and Lewandowsky (2004) is source monitoring; as subjective adequacy in descriptions reduces, more conservative responses should be expected (cf. Sauerland et al., 2008; Winkielman & Schwarz, 2001). Participants found irregular arrays the more difficult stimulus set than irregular arrays, therefore it would be expected that conservative responding within the verbalisation group would be more extreme for irregular than regular arrays, yet this did not occur (although note that encoding style did not significantly moderate the relationship between array type and subjective difficulty).

However, the magnitude of the verbalisation-copying difference within the irregular arrays was larger than that of the regular arrays (.28 and .17 respectively)⁴. It is quite possible that a shift in C is more pronounced for irregular materials (which may aid explaining previous failures to replicate the effect which focused solely on hard-to-verbalise facial stimuli; cf. Nakabayashi et al., 2012). Increasing sample size or the number of test trials in future studies would address this point.

However, the findings with respect to array type on recognition support the prior familiarity hypothesis where previous experience with the stimuli benefits discrimination independently of encoding, replicating Nakabayashi et al. (2012); i.e. recognition discrimination was superior for regular arrays where participants would likely have prior experience with the constituent elements leading to more efficient encoding, hence enhanced discrimination. (See also Scott and Dienes (2010d) for work examining the role of prior experience with test materials and experimentally induced familiarity processes.) Thus, the pattern of results suggests that conservative shifts are more strongly implicated in recollection whereas prior familiarity supports overall recognition discrimination where conscious recollection is not necessarily required.

The method used in the current study differs from the post-stimulus encoding procedure by initiating recoding of all to-be-remembered stimuli as opposed to initiating a processing shift. Failures to find evidence of a conservative shift in post-stimulus encoding paradigms suggest it cannot easily be initiated by orienting local processing at the expense of global processing (Clare & Lewandowsky, 2004). However, a central tenet of recoding interference is that verbal information overshadows but does not eradicate visual memory (Schooler & Engstler-Schooler, 1990). ‘Releases’ from verbal overshadowing have been reported in visual imagery when given

⁴ An independent samples *t*-test comparing verbalisation and copying groups on the criterion of R responses within irregular arrays yields $t(41) = 2.88, p = .006$; there was a detectable shift toward more conservative responding following verbalisation. The same comparison within regular arrays gives $t(35) = 1.23, p = .223$. See table 2 for descriptive statistics. To assess evidence for the interaction, the difference between mean differences (0.11, *SE* of the difference = 0.16) was modelled as a uniform with the lower limit set to 0 and the upper limit set to the difference obtained for irregular arrays. This gives a Bayes factor of 1.11, indicating insensitive evidence.

appropriate cues at test (Brandimonte & Collina, 2008) and in recognition studies when participants engage in non-verbal tasks such as listening to classical music or completing a maze between encoding and test (Finger, 2002). Such measures could easily be incorporated into the current experimental procedure which could quite possibly reverse the conservative shift found here, as a criterion shift is inherently a reversible process.

Researchers have noted that different explanations may be more suitable for different domains and more than one form of VO may exist (Chin & Schooler, 2008; Brandimonte & Collina, 2008; Meissner et al., 2008). Importantly, these results do not necessarily refute other accounts of VO particularly as applied to non-recognition studies and different accounts of VO may be more suitable to explain the phenomenon under different circumstances (Lloyd-Jones, Brandimonte & Bäuml, 2008). For example, recognition judgments are not given in visual imagery studies, thus it is unclear how a conservative shift would become manifest in this domain (Brandimonte & Collina, 2008). Similarly, processing shift interpretations are a good fit of post-stimulus encoding studies. Furthermore, it is uncertain how to reconcile criterion shifts with VO effects found in non-visual modalities such as taste (Melcher & Schooler, 1996; Wilson & Schooler, 1991) or auditory processes (Perfect et al., 2002). Nevertheless, evidence of a conservative shift was found in the current study which suggests it can be a product of recoding as opposed to a separate VO theory.

The experiential state of the participant should be accounted for when investigating VO where appropriate. Neglecting this aspect may overlook subtle effects acting differentially on recognition experiences (recollection, familiarity, guessing). Copying stimuli to result in a veridical memory trace could also be considered, where suitable, in future VO studies (Walker, Blake & Bremner, 2008; Walker, Kenneedy & Berridge, 2011), as well as assessing the contribution of prior familiarity with the materials (Nakabayashi et al., 2012). This study provides evidence that a conservative criterion shift in remember judgments can occur over multiple test stimuli, and reduce memory strength due to non-veridical encoding, potentially

irrespective of whether stimuli are easy- or difficult-to-name (Clare and Lewandowsky, 2004).

The results begin to establish boundaries under which conservative shifts may be found.

Chapter VII

Conclusions: Analysis and synergy in learning and memory research

The primary aim of this thesis was to explore the similarities and differences of processes underlying performance in artificial grammar learning and remember/know studies, and additionally exploring wider theories of cognition, predictions derived from which lend themselves more readily to one paradigm over the other. Chapters II and III explored the speed of mental processes relevant to sequence classification in AGL. Predictions derived from dual process theory and applied to AGL (specifically that familiarity is a fast, automatic process compared to the slower and controlled recollection process) were, with some caveats, borne out. Chapter II showed that grammaticality responses without an accompaniment of conscious metacognitive evaluation of grammaticality (i.e.: guess responses as shown by bets on the random 50:50 process) were made more slowly than when judgment knowledge was conscious. However, when this type of response was externally enforced, decisions could be made rapidly and with little decline in quality. Responses with conscious judgment knowledge, however, did suffer a speed-accuracy trade-off. This result is in-line with the Dewhurst, Holmes, Brandt and Dean (2006) interpretation of dual process theory: that is, people await a metacognitive process to complete before making a decision. If this process is not successful in producing a feeling of knowing, then they opt to guess. Yet the (unconscious) knowledge underlying that judgment is as well formed as it will ever be more rapidly than when conscious judgment knowledge is available. Interestingly, people experienced conscious judgment knowledge in as many short deadline trials as long ones, suggesting this metacognitive process begins rapidly but is unreliable when not enough time is available for completion. However, the no-loss gambling procedure conflates responses based on any degree of confidence. When betting on the grammaticality decision, structural knowledge could be conscious or unconscious, both of which are accompanied with conscious judgment knowledge. Thus Chapter III sought to

establish whether conscious or unconscious structural knowledge was the driving force behind the reduction in decision accuracy. Dual process theory suggests it should be recollection that is impaired under speeded conditions (for review, see Yonelinas, 2002). However, alternative predictions were derived from quite separate theories of conscious experience – Higher Order Thought Theory (e.g. Rosenthal, 2000) and Cross-Order Integration Theory (e.g. Kreigal, 2007). In fact, the results of Chapter III corroborated both theories. When decisions were unspeeded, response times increased with decreasing availability of grammar metaknowledge (conscious structural knowledge responses were made most rapidly, followed by unconscious structural knowledge with conscious judgment and then those based on unconscious judgment and structural knowledge). This follows the same pattern as the results of Dewhurst et al (2006) who found R responses were made most rapidly, followed by K and then G responses. The introduction of response deadlines revealed a double dissociation: conscious structural knowledge responses retained their accuracy but fewer of these response types were made and unconscious structural knowledge with conscious judgment suffered reduced accuracy but the proportion of these trials was retained. This suggests that the processes – or phenomenological experiences – underlying rule and recollection judgments in AGL are similar to those underlying R responses in R/K (Tunney, 2007), specifically that applying a recollective memory to a given stimulus is cognitively effortful as it is consciously controlled and therefore time-consuming. Similarly, although the accuracy of intuition and familiarity did undergo a reduction in quality under the deadline, accuracy remained substantially above chance, in-line with dual process theories of recognition and indicative of a rapid familiarity response. This may share similarities with those of Knott and Dewhurst (2007) who found divided attention at test impaired K responses but not R responses. Interrupting a continuous stimulus-bound evaluative process can only lead to impairment in that evaluation. This is in contrast with a strong symbolic event, which can survive some interruption, but if the knowledge which underlies that event is complex in nature, then interruption can lead to an all-or-nothing impairment (i.e. accuracy is retained when such knowledge can be applied but when not, the participant does not *report* having the recollective experience). Chapters II and III suggest that responses made with

conscious judgment knowledge show differential response times and behave differently under time pressure depending on the conscious status of structural knowledge, which themselves are different from those made with unconscious structural and judgment knowledge. Quite separate theories of cognition (dual-processes in recognition; higher order thought and cross-order integration) are supported by this pattern. It turns out that a distinction between conscious and unconscious judgment knowledge for unconscious structural knowledge is needed to explain the results in Chapter II; namely being conscious renders continuously graded knowledge vulnerable to interference (a prediction derivable from higher order and cross order integration theories). But a further distinction between conscious and unconscious structural knowledge is needed to explain the results from Chapter III, where being conscious rendered protection to knowledge by virtue of being symbolic rather than continuous (consistent with some dual process theories of learning, e.g. Sun, 2002)

Chapter IV revealed that conscious structural knowledge emerges earlier in the AGL test phase when explicit feedback is provided, in line with the dual-process model of Scott and Dienes (2010). The accuracy of this knowledge was maintained throughout and not improved by feedback. However, the accuracy of unconscious structural knowledge accompanied with conscious judgment knowledge was reduced over the course of testing but was maintained with feedback. This supports the notion that feedback sustains the use of the products of implicit learning in naturalistic settings. Furthermore, without feedback, sources of familiarity can become confounded. Contaminated familiarity may then be expressed automatically when the individual is unaware of learning a second set of regularities (cf. Higham, Pritchard & Vokey, 2000). However, feedback allows competing familiarity signals to be contextualised (Wan et al, 2008), hence discrimination ability retained. Feedback does not impact on conscious structural knowledge responses; that is when knowledge extends beyond the use of familiarity. The results suggest implicit learning occurs beyond the training phase in AGL (see also Dienes & Altmann, 1997; Lotz, Kinder & Lachnit, 2009; Redington & Chater, 1996), a result unlikely to be found using R/K methods where familiarity based forgetting occurs during an intermediate delay (e.g.:

Yonelinas & Levy, 2002). The contextualisation of familiarity is quite inconsistent with the definition of an automatic process that occurs independently of intentions (e.g. Jacoby, 1991), but is not inconsistent with its definition as an indication of ‘oldness’ that emerges from learning (Dienes, Scott & Wan, 2010; Scott & Dienes, 2010). Future research should investigate the limits of how intentions impact upon the expression of unconscious structural knowledge and its flexibility compared to conscious structural knowledge. Furthermore, the robustness of familiarity as a product of implicit learning should be compared to that of list learning (as in R/K methods) to further establish their potential (dis)similarities. Indeed, two opposing predictions may be derived regarding how feedback may affect recognition, assuming familiarity traces underlying implicit learning and recognition performance are similar: The MINERVA 2 model (e.g.: Hintzman, 1984) may predict a greater false alarm for semantically related lures, as a familiarity trace may activate conceptually similar memory contents, whereas the findings in the false memory literature predicts the opposite, in that feedback has been shown to reduce the rate of false memories (Fazio & Marsh, 2010; McConnell & Hunt, 2007). This is a matter for future testing.

Turning to theories on the relationship between types of thought and task performance, Chapter V showed that a period of ‘unconscious thought’ after information acquisition in AGL results in improved accuracy of judgments made without conscious judgment knowledge compared to immediate decision making or task-relevant conscious deliberation. This was the only subjective experience under which evidence favouring deliberation without attention was found. This finding is appealing as one may expect beneficial effects of a theory positing a powerful unconscious to foster unconscious representations. However, the products of unconscious thought are said to manifest themselves in intuition-based decisions (Dijksterhuis & Nordgren, 2006); in AGL these would be considered those based on the conscious judgment of unconscious structural knowledge. Yet, this did not occur (indeed, the Bayes factor favoured the null hypothesis). It could be the case that that not enough time was given for the products of unconscious deliberation to transfer to decisions made with conscious judgment knowledge, or

that a period of distraction increased the accuracy of judgments towards grammar sequences falling close to subjective mean familiarity (Scott & Dienes, 2010) perhaps through the clearing of interference (Shanks, 2006). As it was unclear whether unconscious thought produced a change in response bias, discrimination or both, future research could consider this question more fully. Chapter V tentatively supports the relevance of a distinction between conscious and unconscious judgment knowledge, but as a significant difference was not obtained in unconscious thought effects between these two types of knowledge, the use of unconscious thought effects to distinguish those knowledge types remains conjectural. In their recent meta-analysis, Strick et al (2011) give suggestions regarding how to replicate the unconscious thought effect, including the provision of a general impression formation goal and inducing a configural rather than featural mind-set, which could be incorporated into AGL studies or other paradigms thought amenable to replicating the unconscious thought effect. Such suggestions are reminiscent of the moderating factors behind other theories related to how modes of thought affect task performance.

Chapter VI examined VO in recognition, specifically investigating the antecedents of the criterion shift account and additionally evaluating how experiences of recognition were affected by verbalisation. It was found that verbal recoding of the visual stimuli led to more conservative remember judgments for both easy- and hard-to-name stimuli (the data were insensitive in detecting a further raising of criterion for hard-to-name stimuli), and replicated the finding that prior familiarity with materials supports recognition (e.g. Nakabayashi et al., 2012). Furthermore, verbalisation led to fewer remember judgments and a corresponding increase in guessing. Verbal processing raised the threshold of evidence demanded by participants to elicit a feeling of recognition and, within recollection, participants were more tentative in their endorsements. This effect is likely due to the degree of superficial perceptual matching varying as a function of encoding styles and the test modality (Rajaram, 1993) This shows fewer subjective experiences, or feelings of, of recognition (Wixted & Mickes, 2010, Gardiner, Ramponi & Richardson-Klavehn, 2002) occurred due to the engagement of verbal recoding

compared to the use of a more veridical encoding style (copying). This pattern of results largely supports the criterion shift account of VO (Clare & Lewandowsky, 2004), but begins to establish boundaries where such an effect may be expected; namely as a transition between experiences of recognition and a higher threshold within recollection. Furthermore, conservative responding may be the manifestation of recoding interference. The inclusion of subjective reports should be considered in future VO studies (cf. Lloyd-Jones & Brown, 2008).

More broadly, it is thought that other forms of VO may exist in different domains (Chin & Schooler, 2008). For example, recoding interference is a good fit of the data in imagery and mental rotation (Brandimonte & Collina, 2008); interference induced by post-stimulus encoding verbalisation is thought to result in an inappropriate processing shift (Lloyd-Jones & Brown, 2002, 2003); VO effects extend beyond the visual modality to voices (Perfect, Hunt & Harris, 2002) and taste (Melcher & Schooler, 1996); and VO-like deficiencies can be observed by merely re-orienting focus without engaging verbal processing (Macrae & Lewis, 2002). Thus the effect is general and it is doubtful one mechanism can account for all the extant findings. Nonetheless, the products of UTT may also be thought to be quite general and have been implicated in creativity (Dijksterhuis & Meurs, 2005), prediction (Dijksterhuis, Bos, van der Leij, van Baaren, 2009) and morality (Ham & van den Bos, 2010). Both VO and UTT are concerned with effects of modes of thought upon performance and, indeed, VO can also be attenuated ('released') by the engagement in non-verbal tasks, such as completing a maze or listening to music (Finger, 2002), which may be similar to distraction as described by UTT. The active cognitive operators responsible for both deficits and advantages in VO and UTT may be quite similar and future research should aim to reconcile the two, especially considering that specific processing strategies can make participants sensitive to particular elements in structured stimuli (Whittlesea & Dorken, 1993; Whittlesea & Wright, 1997). For example, incorporating the verbalisation manipulation used in Chapter VI into an AGL paradigm would test whether VO extends to implicit learning and in what manner its effects relate to the products of unconscious thought and whether the findings on recognition processes extend to judgment and

structural knowledge as they relate to AGL. This would build upon the findings of Chapter III, which provided some evidence that not allowing participants to make their grammaticality judgment until after an enforced time period appears to harm the accuracy of conscious structural knowledge (perhaps to a greater extent than unconscious structural knowledge). Too much rumination over a decision can reduce its quality (Wilson & Schooler, 1991) and self-paced conscious thought can produce advantages over an enforced period of thought (Payne, Samper, Bettman & Luce, 2008). Although participants were not directly instructed to use the entire five second period to consider their decision in Chapter III (Experiment 2), if they did so naturally then the relative deterioration in the performance of their conscious structural knowledge (compared to Experiment I) may be explained by a VO-like effect. This is a matter for future testing.

This thesis has built upon the distinction between unconscious and conscious knowledge of structure, where the former is heavily reliant on a familiarity process and the latter involves a conscious recollection process. Dienes and Scott (2005) were the first to operationalise knowledge types according to this distinction, finding that the accuracy of conscious structural knowledge was hampered by divided attention and that reliance on this type of knowledge was increased when participants deliberately attempted to learn materials, thus showing these categories behave in accordance with theory (further explicated in Dienes, 2008a; Scott and Dienes, 2010a). These findings are similar to the behaviour of recollection and familiarity processes according to dual process theory of recognition (Yonelinas, 2002; see also Tunney, 2007), and this thesis explores the similarities and differences between the structural knowledge types and recognition types. The distinction is furthered in Chapter III where it was shown that unconscious structural knowledge takes longer to be expressed, independently of confidence, and suffers a greater speed-accuracy trade-off than conscious structural knowledge; in Chapter IV where feedback maintained the accuracy of unconscious structural knowledge compared to no feedback, and feedback had no detectable effect on conscious structural knowledge; and in Chapter VI where a non-veridical encoding style reduced reliance on a

recollection process (and made such responses more conservative) compared to veridical encoding. However, the conscious-unconscious distinction may be as important for judgment as structural knowledge. Chapter II revealed no evidence of a speed-accuracy trade-off for unconscious judgment knowledge. Chapter III showed the time taken to make a response based on unconscious judgment is longer than for unconscious structural knowledge accompanied with conscious judgment, independently of differences in confidence and accuracy. Chapter IV indicated some evidence that external feedback accelerates familiarity calibration (Scott & Dienes, 2010a), reducing the accuracy of unconscious judgment knowledge early in the AGL test phase (note that an orthogonal analysis did not detect a between group difference, so this conclusion is tentative). Chapter V revealed that the products of unconscious thought within an AGL task benefit responses without a conscious metacognitive experience of grammaticality, but did not improve decisions made with conscious judgment knowledge (see also Scott and Dienes, 2010c, for unconscious judgment knowledge modality transfer in AGL). Finally Chapter VI showed that verbalisation led to a greater reliance on guessing in a recognition memory task than a veridical encoding style indicating a conscious feeling of familiarity was inhibited when encoding was non-veridical, i.e.: recoding interference increased the amount of non-knowing compared to self-knowing (Tulving, 1985). The single process theory of unconscious structural knowledge (Scott & Dienes, 2010a) states that, in AGL, guess responses occur when the mean familiarity of a test item falls close to the subjectively defined mean, and such responses are exacerbated before classifications and familiarity become calibrated. Guess responses in recognition occur when an item falls close to the old/new recognition criterion (Wixted and Mickes, 2010; Gardiner et al, 2002), and, in R/K studies, are often treated as noise to be discarded. Nonetheless, given sufficiently sensitive tools, unconscious judgment knowledge can be picked out and used as the object of study. Isolating these responses and careful analysis of when they occur may shed new light on the underlying processes. Different theories, methodologies and operationalisations carve up nature in different ways. The divide between conscious and unconscious structural knowledge is one distinction that has become

apparent; the divide between conscious and unconscious judgment knowledge may prove equally real. We are just starting to address this notion.

This thesis has highlighted differences and similarities between theories concerned with conscious and unconscious influences on learning and memory. Future research should increase focus on drawing together seemingly disparate areas of cognition, for example by specifying when recollection-type or intuitive-based processes guide behaviour and under what circumstances responses made without conscious metaknowledge of anything task relevant can be successful, and deriving predictions from one theory or method that should apply to another. As Mathews (1997) states, “Cognitive psychologists are better at analysis than at synthesis” (p 38). When researchers strive for parsimonious explanations of cognition, they aim for both adequacy and frugality (Brainerd & Reyna, 2002). An adequate theory encompasses sufficient breadth to explain enough phenomena and thus be of use. However, frugality is also desirable: sufficiently explaining enough phenomena with fewer assumptions is more desirable than with more. To take one example, Evans (2008) reviews dual-process theories of lower versus higher cognition and identifies fourteen different, yet highly similar, posited dichotomous terms for and features of the two processes (e.g. System 1; Impulsive; Intuitive contrasted with System 2; Reflective; Analytic). Almost all theories reviewed by Evans compare systems which are thought to be unconscious, rapid, automatic and high capacity with those which are conscious, slow, deliberate and capacity-limited. A “grand” dual-process theory which can explain, for example, reasoning, decision making and social cognition, as well as learning and memory may not be possible (indeed, otherwise so many different terms for lower- and higher-order cognition would likely not have come about), but where common themes do emerge, they should be capitalised upon. Testing predictions derived from one theory or method as applied to another is one way for this aim to be achieved.

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Appendix

Chapters II, III, IV.

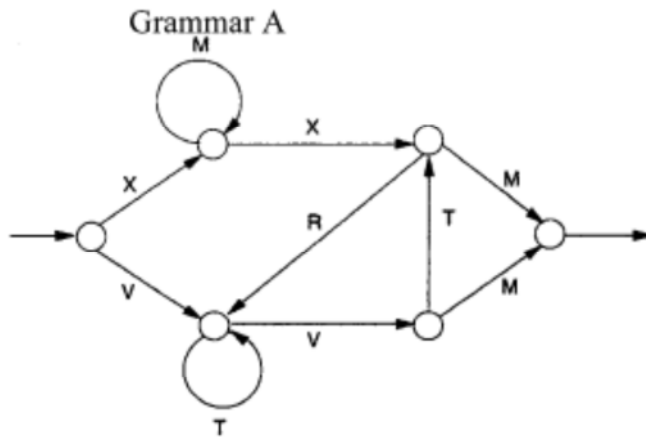


Figure 1a: Grammar A used to generate sequences in Chapters II, III and IV.

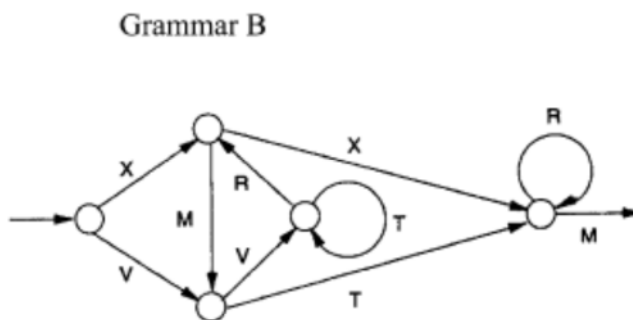


Figure 1b: Grammar B used to generate sequences in Chapters II, III and IV.

Chapter V.

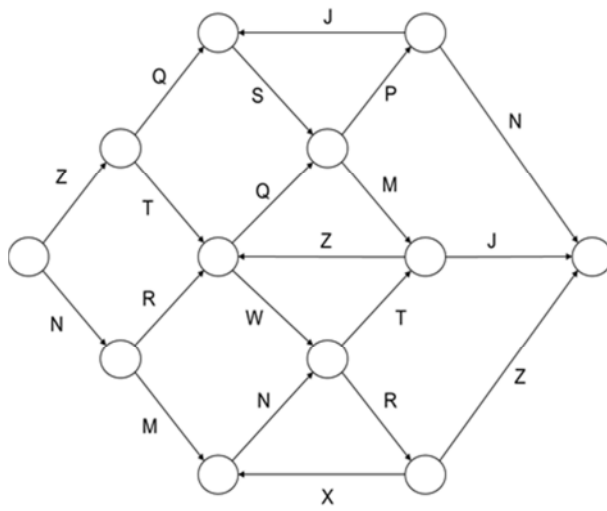
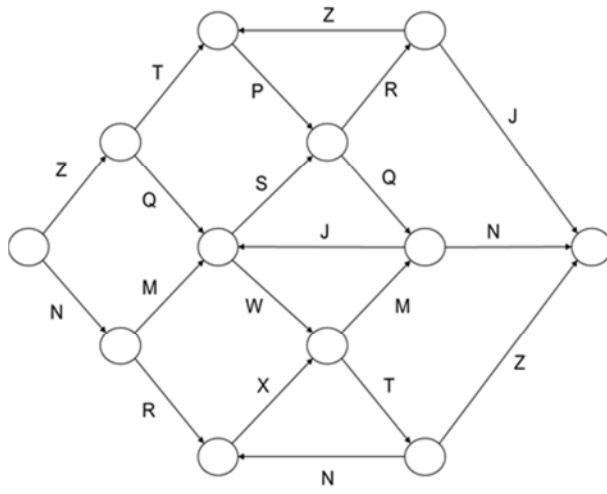


Figure 2a: Grammars used in Chapter V. Grammar S1 (top) taken from Van den Bos & Poletiek (2008). Grammar S2 (bottom) adapted from S1. Topological entropy = 0.55

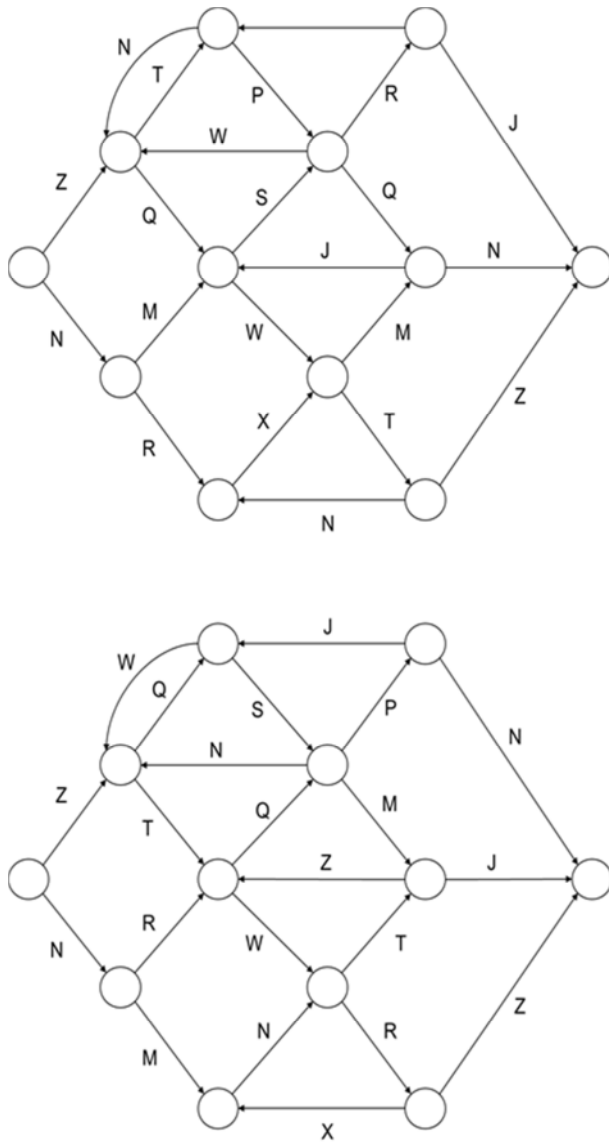


Figure 2b: Grammars used in Chapter V. Grammar C1 (top) taken from Van den Bos & Poletiek (2008). Grammar C2 (bottom) adapted from C1. Topological entropy = 2.05

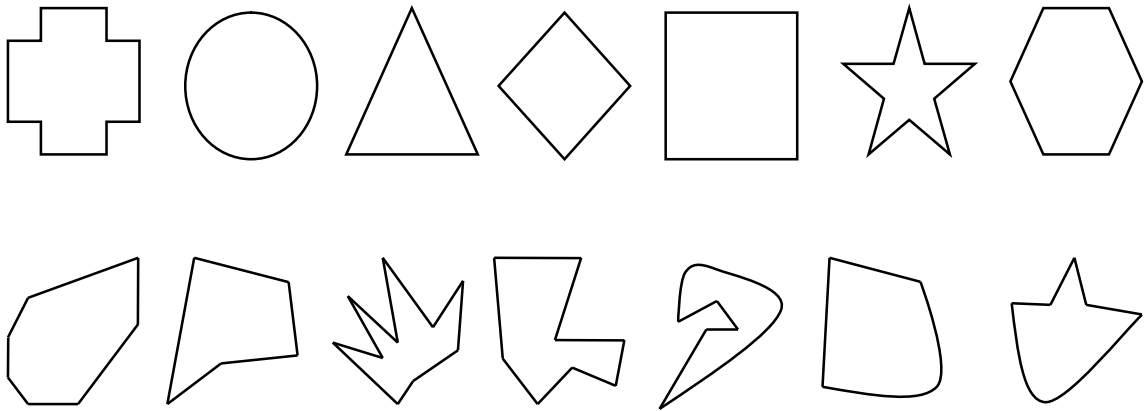
Chapter VI.

Figure 3: Regular (top) and irregular (bottom) elements used to create arrays in Chapter VI. Each shape from left to right was assigned an arbitrary number from 1-7 to generate arrays.