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

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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 controlling for differences in confidence and accuracy. 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).

1. 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 onto 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

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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, and Pasquali, Timmermans, & Cleeremans, 2010, for models of how judgment knowledge may become conscious. See Fig. 1 for the relationship between the conscious status of knowledge types and the associated phenomenology.)

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; Scott & Dienes, 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 (Persaud, 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, 2010). 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), satisfying the guessing criterion of unconscious knowledge (Dienes et al., 1995). This shows participants could express unconscious structural knowledge when judgment knowledge was unconscious.

Mealor and Dienes (2012a) 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 et al., 2007; Henson, Digg, Shallice, Josephs, & Dolan, 1999; Konstantinou & Gardiner, 2005; Wheeler &

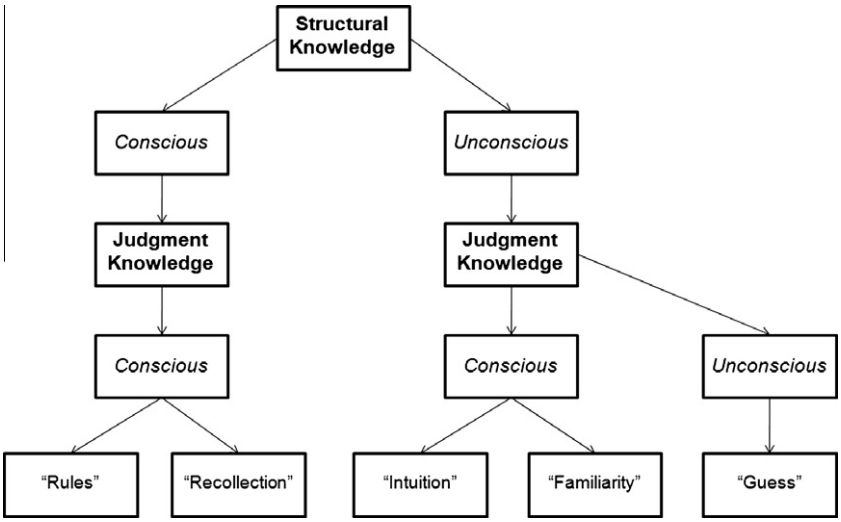

Fig. 1. The relationship between the conscious status of structural and judgment knowledge. The bottom row represents self-reported structural knowledge attributions (Dienes and Scott, 2005; Scott and Dienes, 2008).