Consciousness and Cognition 42 (2016) 229–236

Contents lists available at ScienceDirect

Consciousness and Cognition

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

The relationship between strategic control and conscious structural knowledge in artificial grammar learning

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ARTICLE INFO

Article history:
Received 9 December 2015
Revised 14 March 2016
Accepted 22 March 2016

Keywords:
Implicit learning
Artificial grammar learning
Control
Strategic control
Flexibility
Consciousness
Awareness
Unconscious knowledge
Decision strategy

ABSTRACT

We address Jacoby's (1991) proposal that strategic control over knowledge requires conscious awareness of that knowledge. In a two-grammar artificial grammar learning experiment all participants were trained on two grammars, consisting of a regularity in letter sequences, while two other dimensions (colours and fonts) varied randomly. Strategic control was measured as the ability to selectively apply the grammars during classification. For each classification, participants also made a combined judgement of (a) decision strategy and (b) relevant stimulus dimension. Strategic control was found for all types of decision strategy, including trials where participants claimed to lack conscious structural knowledge. However, strong evidence of strategic control only occurred when participants knew or guessed that the letter dimension was relevant, suggesting that strategic control might be associated with – or even causally requires – global awareness of the nature of the rules even though it does not require detailed knowledge of their content.

1. Introduction

The ability to strategically control the influence of knowledge on behaviour is regarded by many as indicating that the knowledge is conscious (e.g., Baars, 1988; Jacoby, 1991). However, this assumption has been challenged by empirical findings showing that unconsciously perceived stimuli can interfere with tasks traditionally thought to require strategic control (Lau & Passingham, 2007; Schmidt, Crump, Cheesman, & Besner, 2007; Van Gaal & Lamme, 2012; Van Gaal, Ridderinkhof, Scholte, & Lamme, 2010). The idea of unconscious executive control is also inherent in Dienes and Perner's (2007) cold control theory of hypnosis. In the present study we address whether and to what extent strategic control over the application of 2 rule sets in artificial grammar learning (AGL; Reber, 1967) requires conscious structural knowledge of those rule sets.

Strategic control can be measured by comparing performance in situations where the person tries versus tries not to engage in some act, i.e. situations that require "opposition logic". For example, Jacoby's (1991) Process Dissociation Procedure aims to identify dissociations between automatic and intentional application of knowledge by comparing performance under conditions where participants are instructed to apply, versus withhold, certain knowledge. This logic has been applied to implicit learning experiments, including artificial grammar learning (AGL; Reber, 1967, 1993). In AGL, participants initially observe or memorize a series of nonword letter strings where the identity and order of letters is determined by a complex

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http://dx.doi.org/10.1016/j.concog.2016.03.014
1053-8100/

finite-state grammar. After this training phase they are told that all letter strings followed a complex set of rules, referred to as a grammar. In a subsequent test phase they judge the grammaticality of a series of novel letter strings.

Consciousness of acquired knowledge can be assessed by various subjective awareness measures (Pasquali, Timmermans, & Cleeremans, 2010; Sandberg, Timmermans, Overgaard, & Cleeremans, 2010). If participants are trained on two different grammars, strategic control can be measured by asking them to selectively apply their knowledge of one of these grammars over a given block of test trials (Dienes, Altmann, Kwan, & Goode, 1995; Wan, Dienes, & Fu, 2008; see also Higham, Vokey, & Pritchard, 2000). An alternative procedure – argued to require a higher degree of strategic control – is to let the classification rule vary randomly between individual trials (Norman, Price, & Jones, 2011). Translated to opposition logic, such classification judgements require the "inclusion" of strings that follow the target grammar and "exclusion" of strings that follow the irrelevant grammar. The same logic has been applied to implicit sequence learning in the serial reaction time (SRT) task (Nissen & Bullemer, 1987). Here strategic control is measured as the ability to avoid generating regularities from the trained sequence under exclusion as opposed to under inclusion instructions (Destrebecqz & Cleeremans, 2001; Fu, Fu, & Dienes, 2008; Goschke, 1998; Jiménez, Vaquero, & Lupiáñez, 2006; Wilkinson & Shanks, 2004). More demandingly, it has been measured as participants' ability to indicate anticipated target positions when the instructed relation between the spatial location of the anticipated target and the spatial location of a manual response varies across trials (Norman, Price, Duff, & Mentzoni, 2007). Using these procedures, strategic control has been identified both in AGL and SRT learning.

One of Jacoby's central assumptions, which is consistent with Baars' (1988) Global Workspace Theory, is that strategic control over the application of knowledge requires conscious awareness. In memory experiments, this is taken to specifically require conscious recollection of previously exposed stimuli. One example is word stem completion under exclusion instructions, where participants complete a series of word stems with words that have not been presented earlier (Jacoby, Toth, & Yonelinas, 1993). According to Jacoby et al., the controlled suppression of a word that comes to mind during this task requires participants to consciously recollect having seen the word during training. This in turn requires accurate source identification – i.e., that one consciously attributes generated words to previous exposure (Buchner, Erdfelder, Steffens, & Martensen, 1997; Yu & Bellezza, 2000). In contrast, words that come to mind which are not attributed to previous exposure are more likely to be reported contrary to instruction.

In the current paper we explore the extent to which strategic control over the application of two learned grammars in AGL is limited to instances where participants attribute their classification responses to conscious decision strategies, and/or where there is conscious awareness of which stimulus dimension was relevant to the grammaticality decision. The question is relevant to the proposed distinction between two forms of knowledge that may be acquired in AGL: (a) judgement knowledge – i.e. knowledge of *whether* a certain letter string is grammatical, and (b) structural knowledge – i.e. knowing the *detailed structure* of the grammar (Dienes & Scott, 2005). What we ask is whether and to what extent the ability to strategically control one's grammaticality judgement requires *conscious* structural knowledge.

In AGL, whether structural knowledge of grammar rules is conscious or unconscious can be assessed in at least two different ways. First it can be assessed by asking participants, on every test trial, to report the decision strategy they used to arrive at their classification judgement (Dienes & Scott, 2005). If participants report using "explicit rules" or "memories" one would infer the involvement of conscious structural knowledge. However if they report using "random choice", "intuition", or "familiarity", commonly referred to as "implicit" decision strategies, one would infer that any above-chance classification performance reflected unconscious structural knowledge (Scott & Dienes, 2008). In both SRT and AGL experiments, it has been found that strategic control can occur even for decisions attributed to implicit strategies (Fu, Dienes, & Fu, 2010; Wan et al., 2008). Second, whether structural knowledge of grammar rules is conscious or unconscious can be assessed by asking participants to identify which stimulus dimension(s) are relevant to the learned rules. If participants report that the rules were related to a dimension that was indeed relevant to the rules, e.g., the selection and ordering of letters in AGL, one would infer that they might have conscious structural knowledge. By contrast, the unconscious nature of structural knowledge could be safely inferred if participants report that they thought the rules were related to stimulus dimensions that were in fact irrelevant. For instance, if letter strings in AGL contained additional random variation in colour which was irrelevant to the grammar, a participant truthfully attributing the rule to colour variations only, would not have correct conscious structural knowledge. There is already some evidence that even participants who misattribute the nature of acquired rules to irrelevant stimulus properties may still strategically control the application of knowledge, both in AGL (Norman et al., 2011) and SRT experiments (Norman et al., 2007).

It may be argued that the two measures reflect different properties of structural knowledge: Self-reported decision strategy reflects the extent to which participants feel they applied conscious structural knowledge and/or conscious judgement knowledge, whereas reported rule-dimension awareness, i.e., the extent to which participants reported that their decision involved the letter dimension, reflects the accuracy of participants' hypotheses about of the nature of the grammar. The two may often converge, as when making an intuitive judgement relating to an irrelevant stimulus dimension, which would be a strong indication that structural knowledge was indeed unconscious, or conversely applying a conscious rule that relates to a relevant stimulus dimension. However, the two may also diverge. For instance, a consciously applied rule may well relate to one or more irrelevant stimulus properties (e.g., "when a word contains many purple letters and at least one letter is written in italics it must belong to Grammar A").

It could also be argued that used individually, both measures have limitations. First, they reflect different properties of structural knowledge: Self-reported decision strategies reflect whether participants feel they *applied* conscious versus unconscious structural knowledge, whereas reported rule awareness reflects whether the *content* of participants' hypotheses