Consciousness and Cognition 28 (2014) 1–16

Contents lists available at ScienceDirect

Consciousness and Cognition

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

Role of prior knowledge in implicit and explicit learning of artificial grammars ☆

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ARTICLE INFO

Article history:
Received 27 July 2013

Keywords:
AGL
Implicit learning
Explicit learning
General knowledge
Similarity
Rules

ABSTRACT

Artificial grammar learning (AGL) performance reflects both implicit and explicit processes and has typically been modeled without incorporating any influence from general world knowledge. Our research provides a systematic investigation of the implicit vs. explicit nature of general knowledge and its interaction with knowledge types investigated by past AGL research (i.e., rule- and similarity-based knowledge). In an AGL experiment, a general knowledge manipulation involved expectations being either congruent or incongruent with training stimulus structure. Inconsistent observations paradoxically led to an advantage in structural knowledge and in the use of general world knowledge in both explicit (conscious) and implicit (unconscious) cases (as assessed by subjective measures). The above findings were obtained under conditions of reduced processing time and impaired executive resources. Key findings from our work are that implicit AGL can clearly be affected by general knowledge, and implicit learning can be enhanced by the violation of expectations.

1. Introduction

The present work uses the AGL paradigm to explore the effect of prior knowledge on (implicit and explicit) learning. Most AGL studies use meaningless stimuli, devoid of any correspondence with prior knowledge. Moreover, the majority of AGL models reference only the structural aspects of stimuli (e.g., Boucher & Dienes, 2003; Cleeremans, 1993a, 1993b; Dienes, Altmann, & Gao, 1999; Servan-Schreiber & Anderson, 1990; but see Dienes & Fahey, 1995; Sun, 2000). Extending the AGL paradigm to a knowledge-rich version is crucial in determining whether AGL theory can extend to more realistic learning conditions and whether AGL tasks can be employed to shed light on how general knowledge can influence cognitive processes.

In a typical AGL experiment (e.g., Dulany, Carlson, & Dewey, 1984; Reber, 1967; Reber & Allen, 1978), participants first study a list of letter strings generated by a finite state grammar and are asked to simply observe them or memorize them.

☆ Emmanuel M. Pothos was supported by Leverhulme Trust grant RPG-2013-004 and by Air Force Office of Scientific Research (AFOSR), Air Force Material Command, USAF, grant FA 8655-13-1-3044. The U.S Government is authorized to reproduce and distribute reprints for Governmental purpose notwithstanding any copyright notation thereon.

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http://dx.doi.org/10.1016/j.concog.2014.06.003

After training, they are informed that the strings followed a complex set of rules, but no specific information is provided regarding the nature of the rules. Then, they are asked to classify new letter strings, half of which are consistent with the rules and are thus called grammatical (G) and half of which are not consistent with the rules and are called non-grammatical (NG). No corrective feedback is provided in the test phase.

Replacing the letter strings in the standard AGL paradigm with meaningful stimuli (e.g., sequences of cities), without any more elaborate prior knowledge manipulation, does not seem to alter performance (Pothos, Chater, & Ziori, 2006). Pothos (2005, Experiment 2) used sequences of cities and also manipulated the consistency of stimulus structure with instructions given to participants, to induce different expectations about the stimuli. In his relevant experiment, the stimuli were sequences of cities that corresponded to the routes of a salesman. In one condition, stimulus structure was consistent with participants' expectations from the instructions (that the salesman should make as many short trips as possible), whereas in the other it was not. When stimulus structure was inconsistent with expectations, performance was impaired. At the very least, the study of Pothos (2005) shows that expectations about stimulus structure can affect AGL performance. However, Pothos (2005) used only a simple incidental learning condition and measured AGL performance only in terms of grammaticality accuracy. Further, Pothos did not employ any measures of the implicitness of the acquired knowledge. The present work extends Pothos's (2005) study, to explore the generality of his findings. In particular, we disentangle three knowledge types, namely general knowledge relations that are consistent or inconsistent with people's expectations and two purely structural aspects (i.e., grammaticality and similarity). We also use subjective measures of implicitness, to examine the implicit or explicit nature of each knowledge type, under different learning conditions.

1.1. Key features of AGL

A key aspect of AGL tasks concerns stimulus construction. Consider, for example, Fig. 1, which presents the grammar employed in the present experiment.

In going from left to right, a set of G strings are created, as opposed to NG strings. The distinction between G and NG sequences is referred to as 'grammaticality'. Crucially, the relation between the training and test stimuli is not limited to the grammar rules per se: For example, some test items will have bigrams (pairs of symbols) or trigrams (triplets of symbols), which are familiar from training (Perruchet & Pacteau, 1990; Knowlton & Squire, 1996).

There has been a flourishing research tradition and divergent hypotheses on what is learned in AGL, including rules, whole item similarity and similarity based on chunk overlap (e.g., Dulany et al., 1984; Knowlton & Squire, 1996; Perruchet & Pacteau 1990; Reber, 1967; Reber, 1989; Vokey & Brooks, 1992; see Pothos, 2007 for a review). For example, apart from grammaticality, a common measure that has been used in AGL is Knowlton and Squire's (1996) chunk strength index. Chunk strength is estimated by averaging the frequency, with which all chunks (i.e., bigrams or trigrams) of each test item occurred during training (cf. Meulemans & Van der Linder, 1997). When grammaticality and chunk strength are carefully balanced, as is the case in the present work, the former can be thought to constitute more rule-like knowledge (in the sense that it does not depend on frequency, at least of chunks) and the latter more similarity-like knowledge. Henceforth, when we say grammaticality we will imply rule-like knowledge over and above the frequency-dependent distributional characteristics of chunks, and when we refer to similarity we will imply Knowlton and Squire's (1996) chunk-strength index.

AGL has also been widely used in the implicit learning literature. The issue of the implicitness of knowledge has been hotly debated (e.g., Dulany, 2003; Perruchet & Pacteau, 1990; Shanks & St. John, 1994). In this work, we adopt a general definition, according to which *implicit learning* refers to learning without the need for intention (i.e., it can be passive), and

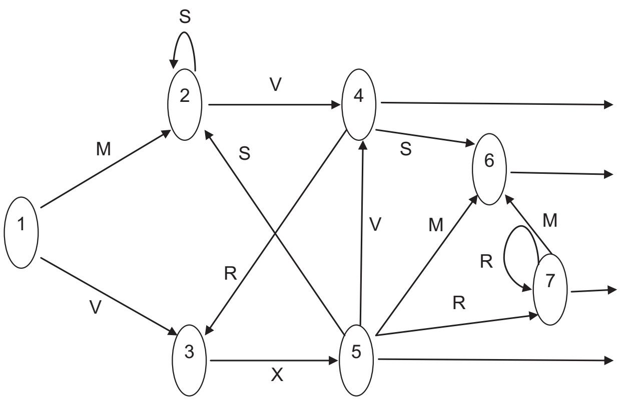

Fig. 1. The present grammar is a deterministic version of Reber and Allen's (1978) classic grammar, though the selection for training and test items was based on the procedure of Bailey and Pothos (2008). *Note*: A nondeterministic grammar can have two (or more) arrows out of a given state that have the same label on each arrow. A deterministic grammar has different labels on all the arrows out of any given state, so if you know what state you are in and what the next symbol is, you know with certainty what the next state is.