Cognition 114 (2010) 372–388

Contents lists available at ScienceDirect

Cognition

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

# Fluency does not express implicit knowledge of artificial grammars

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ARTICLE INFO

*Article history:*
Received 31 December 2008
Revised 21 September 2009
Accepted 14 October 2009

*Keywords:*
Fluency
Familiarity
Implicit learning
Artificial grammar learning
Unconscious knowledge

ABSTRACT

It is commonly held that implicit knowledge expresses itself as fluency. A perceptual clarification task was used to examine the relationship between perceptual processing fluency, subjective familiarity, and grammaticality judgments in a task frequently used to produce implicit knowledge, artificial grammar learning (AGL). Four experiments examined the effects of naturally occurring differences and manipulated differences in perceptual fluency, where decisions were based on a brief exposure to test-strings (during the clarification task only) or normal exposure. When perceptual fluency was not manipulated, it was weakly related to familiarity and grammaticality judgments, but unrelated to grammatical status and hence not a source of accuracy. Counterbalanced grammatical and ungrammatical strings did not differ in perceptual fluency but differed substantially in subjective familiarity. When fluency was manipulated, faster clarifying strings were rated as more familiar and were more often endorsed as grammatical but only where exposure was brief. Results indicate that subjective familiarity derived from a source other than perceptual fluency, is the primary basis for accuracy in AGL. Perceptual fluency is found to be a *dumb heuristic* influencing responding only in the absence of actual implicit knowledge.



## 1. Introduction

There is substantial evidence that the knowledge acquired in implicit learning – especially of artificial grammars – is expressed largely as familiarity, defined as the subjective feeling of oldness elicited by a stimulus (e.g. Higham, 1997; Johnstone & Shanks, 2001; Kinder & Assmann, 2000; Norman, Price, Duff, & Mentzoni, 2007; Scott & Dienes, 2008; Servan Schreiber & Anderson, 1990). The question now arises as to the basis of that familiarity. In the memory literature familiarity has been proposed to result from perceptual or conceptual processing fluency (Jacoby & Dallas, 1981), or surprising fluency (Whittlesea & Williams, 2000). It has been logical to infer that perceptual fluency accounts for familiarity in artificial grammar learning (AGL) and that it is thus the means by which implicit knowledge affects classification either generally or when employing certain strategies (Kinder, Shanks, Cock, & Tunney, 2003; Whittlesea & Price, 2001). However, evidence that perceptual fluency contributes to familiarity is far from conclusive in either recognition memory generally (e.g. Kinoshita, 2002; Levy, Stark, & Squire, 2004; Stark & Squire, 2000; Wagner, Gabrieli, & Verfaellie, 1997) or in AGL in particular (e.g. Chang & Knowlton, 2004; Lieberman, Chang, Chiao, Boohheimer, & Knowlton, 2004; Newell & Bright, 2001; Zizak & Reber, 2004). The current study examines the role of perceptual fluency in AGL, evaluating its influence on subjective ratings of familiarity and grammaticality judgments, and how this influence differs when people can or cannot freely use veridical implicit knowledge.

### 1.1. The role of familiarity in AGL

AGL has been one of the most commonly employed paradigms for the study of implicit learning (Pothos, 2007; A.S. Reber, 1989). In a typical AGL experiment participants are exposed to letter strings conforming to a complex set of rules referred to as a grammar. The strings are commonly

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doi:10.1016/j.cognition.2009.10.010

presented under the guise of a short-term memory task with participants unaware of their rule-based nature. At test, participants are informed of the existence of rules and asked to judge which of a new set of strings are grammatical. Participants are typically able to discriminate the grammatical strings with above-chance accuracy despite believing they are guessing or using intuition and despite being unable to verbalise the rules of the grammar (e.g. Allwood, Granhag, & Johansson, 2000; Channon et al., 2002; Dienes & Altmann, 1997; Dienes, Altmann, Kwan, & Goode, 1995; Dienes & Longuet Higgins, 2004; Dienes & Scott, 2005; A.S. Reber, 1967; Tunney & Altmann, 2001). A.S. Reber (1967) originally proposed that the ability to discriminate grammatical strings resulted from the implicit acquisition of regularities encountered during learning. Since that time research has proceeded to examine the nature of the regularities acquired. These are now known to include commonly recurring fragments or chunks of the training-strings (Dulany, Carlson, & Dewey, 1984; Knowlton & Squire, 1994; Perruchet & Pacteau, 1990; Servan Schreiber & Anderson, 1990), the pattern of repetitions within training-strings (Brooks & Vokey, 1991; Vokey & Higham, 2005), and knowledge of whole training exemplars (Vokey & Brooks, 1992). Similarity between training-strings and test-strings arising from any of these features could in principle result in familiarity. Servan Schreiber and Anderson were the first to characterise the knowledge acquired in this way. The resulting familiarity account holds that grammatical strings, by virtue of conforming to the grammar, are more likely to have properties seen in training and will consequently feel more familiar. Discrimination performance then results from more familiar strings being endorsed as grammatical.

There is considerable evidence supporting this account of AGL. Signal detection analyses of implicit learning tasks are consistent with decisions based on a continuous underlying dimension, such as familiarity, but not with certain rule-based accounts e.g. where a limited number of rules lead to black and white decisions (Kinder & Assmann, 2000; Lotz & Kinder, 2006). Successful computational models of AGL, and implicit learning generally, also assume a continuous output from the network that reflects similarity (for a review see Cleeremans & Dienes, 2008). More directly, Johnstone and Shanks (2001) showed that the objective similarity of training and test-strings strongly predicts grammaticality judgements. Finally, direct evidence has been provided by Scott and Dienes (2008) who showed that subjective ratings of the familiarity of test-strings were reliably predicted by structural similarity measures (mean $R = .45$), and that those familiarity ratings themselves reliably predicted grammaticality judgments (*Mean* $r = .64$).

### *1.2. The fluency hypothesis*

Jacoby and Dallas (1981) proposed that when processing an item with relative ease, or *fluently*, people may attribute this to the item having been seen before and experience it as familiarity. This notion was developed further by Whittlesea and Williams (2000) who demonstrated that familiarity arises from a discrepancy with expected fluency. In AGL perceptual fluency could result from repetition priming during training; the elements most commonly observed in training would subsequently be processed more fluently at test. Given that grammatical test-strings have more in common with training-strings than do ungrammatical test-strings, the resulting difference could, in principle, be a source of accurate responding. Buchner (1994) found evidence supporting grammaticality as a source of differential perceptual fluency in AGL. Employing a perceptual clarification task to measure naturally occurring differences in the perceptual fluency of test-strings, Buchner found grammatical strings to be identified on average 200 ms faster than ungrammatical strings. This is an important and widely cited result. The implication for fluency as a potential source of implicit knowledge both in AGL and implicit learning generally make replication an imperative. The need to explore the generalisability of the effect is particularly acute in light of potential alternative explanations for the differences observed.

Fluency is known to be affected by a range of factors, most obviously repetition. Repetition priming has been demonstrated to enhance perceptual fluency in a range of experimental contexts (e.g. Jacoby & Dallas, 1981; Tulving, Schacter, & Stark, 1982). When parsing a string, if a letter is the same as the previous letter then within-string repetition priming will result in that letter being perceived more fluently. For grammar A of Buchner (1994), the only grammar used in Experiment 1, grammatical test-strings contained more repetitions than ungrammatical strings e.g. TXXTVV vs. TVXTVV. Based on this difference alone, grammatical strings would be expected to be perceived more fluently. However, letter repetition is only one feature known to influence fluency, others include the repetition of larger elements (e.g. bigrams) and the presence or absence of symmetry (R. Reber, Schwarz, & Winkielman, 2004). These superficial features are features that a string has intrinsically, i.e. can be determined from the string alone because they are not a relation between the string and training-strings. All such possible superficial test-string features will be controlled only when grammatical and non-grammatical strings are counterbalanced.

In addition to controlling for alternative sources of fluency, where fluency is assessed using a reaction-time task other influences on response times must also be avoided. In Buchner (1994) Experiment 1 the perceptual clarification task was not followed by any other decision. In Experiment 2, however, participants were required to make grammaticality and recognition judgements after completing the clarification task. Crucially, this was done with the test-string no longer available for reference. Under these circumstances participants might be expected to delay their response to the clarification task until arriving at a decision for the subsequent judgment. Consistent with this influence, the average identification time was 1700 ms longer and the difference between identification times for grammatical and ungrammatical strings 117 ms (66%) greater in Experiment 2 than for the same materials in Experiment 1. Where identification times reflect decision processes, theories from the categorization literature make clear predictions regarding how identification times will be affected. The *RT-Distance Hypothesis*, based on *decision*