RADBOUD UNIVERSITY NIJMEGEN

ADVANCED RESEARCH METHODS

Artificial Grammar Learning using Rapid Serial Visual Presentation

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Abstract

1 Introduction

In our society today, a surefire way of making profit is by developing methods and tools that promise to help us manage life in the fast lane. One of the older methods with this purpose that is gaining in popularity again is the rapid intake of written information, also known as speed reading.

1.1 Speed Reading

Interest in increasing one's reading rate was sparked when Javal drew attention to eye movements during reading through a series of articles published in the 1870s (8, 9, 22). Rather than reading words letter by letter, reading was now seen as an alternating process of fixations and saccades. Each fixation allows good readers to take in on average approximately three words. During saccades, nothing can be seen (1). The American psychologist Renshaw employed tachistoscopes to train pilots of the U.S. Navy in the second World War (2, 6, 17). A tachistoscope is an apparatus that allows the rapid serial visual presentation (RSVP) of stimuli. With this method, saccades could be eliminated by presenting words in the same location. The research regarding the effectiveness of RSVP to increase reading speed produced converging evidence that comprehension suffers under speed reading (3, 4, 12, 19, 21, 23). Despite such evidence, speed reading has recently resurfaced in popular culture in the form of smartphone applications, such as the one by Spritz. Several studies have shown the importance of reading in first and second language acquisition, with reading improving not only comprehension but also inducing an intuition of the underlying syntactic structure (5, 11, 20). Thus, we are not quite ready to write off RSVP as a method for speed reading yet. In this project, we study the possibilities of the method in artificial grammar learning (AGL).

1.2 Artificial Grammar Learning

In the 1960s, Reber studied the implicit learning of stimulus structure. By conducting a series of experiments, he defined three requirements (16, p. 190) for such learning to occur:

1. The rules governing the stimulus material must be complex.
2. Participants should pay close attention to stimuli without searching for underlying rules.
3. Participants should be unable to verbalize the knowledge they obtained during learning.

Reber employed artificial grammars to ensure meeting the first requirement. Artificial grammars are finite state machines with the transition from one state to the next corresponding to one element of the grammar. Grammatical patterns, or words, are created by making only

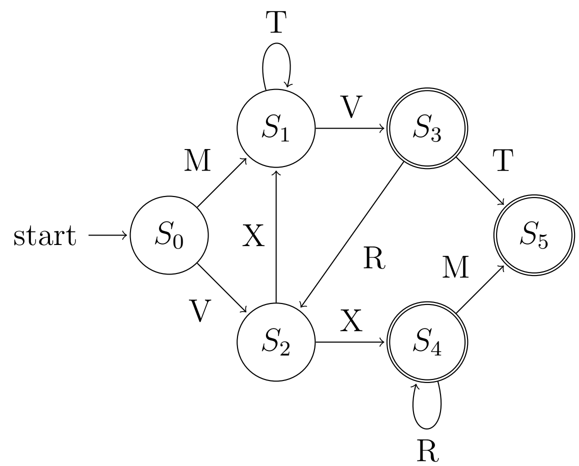

Figure 1: TODO!

allowed transitions from the start state to the final state. The AGL paradigm consists of a learning and a testing phase. In the learning phase, participants are confronted with a set of grammatical words. In his initial studies (14), Reber asked participants to memorize these but later went on to study learning by mere exposure (16). In the testing phase, acquired knowledge is tested by presenting new words and asking participants to judge their grammaticality. This raises the question: How is it possible to develop a feeling for apparently nonsensical patterns? One theory is that implicit learning is statistical learning. This means that the grammatical patterns in the training phase are used to train a classifier within the brain, which tells us the probability for a new stimulus to be a word of the grammar or not (13, 18). While Reber exposed participants to a total of 20 exemplars three times and each exemplar was regarded for ten seconds (16), later studies showed similar results for shorter exposure (Knowlton and Squire (10): three seconds per item with reproduction, Gomez and Gerken (7): total of two minutes).
In this project, we are interested in the possibility of implicitly learning an artificial grammar by viewing exemplars presented in an RSVP paradigm. Specifically, we examine two research questions:

1. Does AGL occur when words are presented individually at the same location at a normal reading rate?
2. Does it also occur at faster presentation speeds (as used by speed reading tools) when
   (a) the same amount of material is presented?
   (b) material is presented for the same amount of time?

To our knowledge, the limitations of AGL have not yet been studied with regard to the presentation speed of exemplars. We generally regard AGL as possible when exemplars are presented at normal and rapid speeds. This is because of the high attentional demand of RSVP (REFERENCE NEEDED) in combination with the importance of attention in implicit learning. However, if implicit learning is statistical learning, we further believe that longer exposure times will most likely lead to more reliable probabilistic inferences, with a repeated exposure potentially making up for a shorter exposure. Therefore, we expect an affirmative answer to research questions 1 and 2b.

2 Results

The total number of correct classifications on the 100 test items, P_C, was determined for each participant. The Shapiro-Wilk test was used to check whether the small samples per condition were drawn from a normally distributed population (24). As a consequence, to compare observed to chance level performance, the Wilcoxon signed-rank test was employed for the *normal* and the *fast-time* conditions, while a one-sample t-test could be used for the *fast-amount* condition. The tests were performed one-tailed because only above chance level performance was of interest. As can be seen from the results of these tests, illustrated in Table X (insert Table), no group performed significantly above chance. Therefore, it would not be sensible to make any statistical between-group comparisons. However, although not significant, both the *normal* and the *fast-amount* groups show weak indications that learning may have occurred. Luckily, there are other measures that can provide additional information on this matter.

	Shapiro-Wilk	**Chance Level Comparison**	***p*-value**
normal	H_1: population not normal	Wilcoxon Signed Rank test	.068
fast-amount	H_0: population normal	One-sample t-test	.057
fast-time	H_1: population not normal	Wilcoxon Signed Rank test	.237

The 100 test items consisted of 50 unique items which were all repeated once. Thus, participants could classify each unique item in one of four ways:

1. Correct-Correct (CC): classified correctly on both presentations
2. Correct-Erroneous (CE): classified correctly on the first presentation but incorrectly on the second
3. Erroneous-Correct (EC): classified incorrectly on the first presentation but correctly on the second
4. Erroneous-Erroneous (EE): misclassified on both presentations

The sum of CC and EE denotes overall consistency. Importantly, "when the status of the item is known, it is always classified correctly; when it is not known, a guess is made." (15, p. 227). Using this simple model as a basis, Reber states that CE, EC, and EE should not be statistically distinguishable from each other, since they all reflect guesses. On the other hand, if EE is significantly greater than the average of CE and EC, it can be inferred that judgments were based on rules that are not representative of the grammar. Furthermore, if the participants actually implicitly learned a correct albeit partial representation of the grammar, CC should be significantly higher than each of the other three variables. Finally, if the difference between CE and EC or EC and CE is significant, it is indicative of forgetting or learning during the testing phase respectively (for an in-depth discussion see Reber (15)). For each group, Table XX shows the means for the four variables. Intuitively, the illustrated behavior of our participants seems representative of guessing behavior on all test items. Paired t-tests for the various combinations of these variables (all are distributed normally within each group) confirms this intuition. EC and CE do not show a significant difference. Thus, there is neither evidence for learning nor for forgetting during the testing phase. When comparing EE to the average of CE and EC, $t(9) \leq -4.216$ and $p < .01$ was obtained for all groups. Furthermore, CC was only significantly higher than EE in the *normal* group ($t(9) = 1.843$, $p = .049$) with the *fast-amount* group showing a trend ($t(9) = 1.758$, $p = .057$). Taken together, this implies that all participants based a considerable amount of their decisions on rules that were not part of the grammar. Only in the *normal* group (and possibly in the *fast-amount* group) were significantly more correct than incorrect rules applied. However, it must be noted that these differences are much smaller and thus much move vague than in the artificial grammar learning literature.

	Group					
	normal		fast-amount		fast-time	
	Mean	SD	Mean	SD	Mean	SD
P_C	53.3	5.8	52.9	5.2	50.9	4.8
CC	37.6	5.8	41.6	5.7	35.4	7.4
CE	16.2	6.8	12.4	4.1	14.8	2.4
EC	15.4	3.9	10.2	5.7	16.2	1.9
EE	30.8	7.5	35.8	7.7	33.6	8.2
consistency	68.4		77.4		50.9	

Lastly, we correlated the number of languages participants speak as well as their prior speed reading experience with their P_C-scores across groups. Slightly negative but non-significant correlations were obtained: $r = -.30$, $p = .11$ for the number of languages and $r = -.23$, $p = .22$ for the speed reading experience.

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