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Implicit Learning of Word Order

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Abstract

Language acquisition is frequently characterized as a process where learning proceeds implicitly, i.e. incidentally and in absence of awareness of what was learned. This article reports the results of an experiment that investigated whether adults can acquire the syntactic structure of a novel language implicitly. Experimental subjects were trained on a semi-artificial grammar under incidental learning conditions, and then tested to determine whether learning took place and to assess whether learning resulted in unconscious knowledge. The results indicate that adults are able to acquire syntactic knowledge of a new language under incidental learning conditions, while processing sentences for meaning, without the benefit of corrective feedback and after a relatively brief exposure period. The results also show that learners are able to transfer knowledge to stimuli with the same underlying structure but new surface features. The measures of awareness further suggest that subjects were aware of having acquired knowledge, but that they were unaware of the nature of this knowledge. The experiment thus provides evidence for the implicit learning of natural language syntax.

Keywords: Implicit learning; Artificial Grammar Learning; syntax; language acquisition; intuition; subjective measures.

Introduction

How humans derive information from the environment implicitly, i.e. without the intention to learn and in absence of awareness of what was learned, is one of the central questions within the cognitive sciences. The process of implicit learning is assumed to underlie the human ability to extract knowledge from complex, rule-governed stimulus domains and, as such, appears to be an elementary and ubiquitous process of human cognition. Everyday life offers many examples of implicit learning. Language acquisition, socialization, music perception and many other learning episodes are widely thought to proceed in an implicit fashion.

Despite the widespread recognition that language acquisition constitutes a prime example of implicit learning (e.g., Cleeremans, Destrebecqz, & Boyer, 1998; Frensch & Runger, 2003; Reber, 1967; Perruchet, 2008; St. John & Shanks, 1997; Winter & Reber, 1994), relatively little effort has been made, within linguistics or experimental psychology, to investigate natural language acquisition within the theoretical framework provided by implicit learning research. The present article reports the results of

an experiment that investigated whether adults can acquire the syntactic structure of a novel language without intending to and without awareness of what they have learned. The experiment constitutes an example of how the theoretical concepts and the methodological framework provided by implicit learning research can be applied to the investigation of natural language acquisition.¹

On measuring awareness

It is generally accepted that the knowledge acquired during standard Artificial Grammar Learning (AGL) experiments is the result of an incidental learning process. However, the question of whether this knowledge is actually “implicit” is highly controversial (Berry, 1996). The case for unconscious learning depends on both our definition of awareness and on the validity of tests used to assess unaware learning. In this study, knowledge was assumed unconscious if participants were unaware of what they have learned, i.e. implicit learning was defined in terms of the product of learning rather than the properties of the learning process. Proposals for measuring awareness in this sense include subjective measures, such as verbal reports and confidence ratings, as well as objective measures, where performance on a direct test (e.g., free generation) is compared to performance on an indirect test (e.g., serial reaction time). The present experiment employed subjective measures to determine whether adults could acquire non-native syntax without becoming aware of the knowledge they have acquired.

Subjective measures Dienes (2004, 2008) has advocated the use of subjective measures in order to assess whether the knowledge acquired during AGL tasks is conscious or

¹ The research literature on language acquisition abounds with studies that employ AGs in order to investigate the basic processes underlying natural language acquisition (Gomez & Gerken, 2000). However, in contrast to implicit learning research, these studies generally do not integrate measures of awareness. This is, of course, in part explained by the fact that infants are incapable to verbally report, indicate confidence levels, or perform on fragment completion tasks. However, many of the experiments conducted, for example, within the statistical learning tradition (see Gomez, 2007, and Saffran, 2003, for overviews) employ children or adults as subjects, which means that basic measures of awareness could be administered. Usually, lack of awareness is assumed but not empirically assessed.

unconscious. One way of dissociating conscious and unconscious processes is to collect confidence ratings (e.g., Dienes, Altmann, Kwan, & Goode, 1995; Kunimoto, Miller, & Pashler, 2001). In AGL, for example, subjects can be asked to report, for each grammaticity judgment, how confident they were in their decision. Dienes et al. (1995) suggested two ways in which confidence rating data could serve as an index of unconscious knowledge. Firstly, knowledge can be considered unconscious if subjects believe to be guessing when their classification performance is, in fact, significantly above chance. Dienes et al. called this the *guessing criterion*. Secondly, knowledge is unconscious if subjects' confidence is unrelated to their accuracy. This criterion, introduced by Chan (1992), was labeled *zero correlation criterion* by Dienes et al. Several studies have shown that performance on standard AGL tasks can result in unconscious knowledge according to these criteria (e.g., Dienes et al., 1995; Dienes & Longuet Higgins, 2004).

Structural knowledge and judgment knowledge A criticism that can be leveled at the use of confidence ratings concerns the type of knowledge that is assessed by this measure. Consider the case of natural language acquisition (Dienes, 2008). As mentioned above, language acquisition is considered a prime example of implicit learning. All cognitively unimpaired adults are able to discern grammatical sentences of their native language from ungrammatical ones, even though they are unable to report the underlying rule-system. However, if asked how confident they are in their grammaticity decisions, most native speakers will report high confidence levels, as in: "John bought an apple in the supermarket." is a grammatical sentence and I am 100% confident in my decision, but I do not know what the rules are or why I am right." Since in these cases accuracy and confidence will be highly correlated, does this mean that language acquisition is not an implicit learning process after all? Probably not. Dienes (2004, 2008; Dienes & Scott, 2005) proposed a convincing explanation for this phenomenon, based on Rosenthal's (1986, 2005) Higher-Order Thought Theory.

Dienes suggested that, when subjects are exposed to letter sequences in an AGL experiment, they learn about the structure of the sequences. This *structural knowledge* can consist, for example, of knowledge of whole exemplars, knowledge of fragments or knowledge of rules (e.g., "A letter sequence can start with an M or a V.") In the testing phase, subjects use their structural knowledge to construct a different type of knowledge, namely whether the test items shared the same underlying structure as the training items (e.g., "MRVXX has the same structure as the training sequences."). Dienes labeled this *judgment knowledge*. Both forms of knowledge can be conscious or unconscious. For example, a structural representation such as "An R can be repeated several times." is only conscious if it is explicitly represented, i.e. if there is a higher-order thought such as "I {know/think/believe, etc.} that an R can repeated several

times." Likewise, judgment knowledge is only conscious if there is a corresponding higher-order thought (e.g., "I {know/think/believe, etc.} that MRVXX has the same structure as the training sequences.") The guessing and the zero correlation criteria measure the conscious or unconscious status of judgment knowledge, not structural knowledge.

Dienes & Scott (2005) assume that conscious structural knowledge leads to conscious judgment knowledge. However, if structural knowledge is unconscious, judgment knowledge could still be either conscious or unconscious. This explains why, in the case of natural language, people can be very confident in their grammaticity decisions without knowing why. Here, structural (linguistic) knowledge is unconscious while (metalinguistic) judgment knowledge is conscious. The phenomenology in this case is that of intuition, i.e. knowing that a judgment is correct but not knowing why. If, on the other hand, structural and judgment knowledge are unconscious, the phenomenology is that of guessing. In both cases the structural knowledge acquired during training is unconscious. Dienes and Scott proposed that in AGL experiments the conscious status of both structural and judgment knowledge can be assessed concurrently by adding source attributions to the confidence ratings in the testing phase. That is, in addition to asking subjects how confident they were in their grammaticity judgments, one also prompts them to report the basis (or source) of their judgments. The following experiment exemplifies how subjective measures can be employed to investigate whether adults are able to acquire the syntactic structure of a new language without awareness.

Method

Participants

Thirty native speakers of English (22 women and 8 men, mean age = 24.3 years) were recruited to take part in this experiment and evenly distributed into experimental and control conditions. The majority of participants (28) were university students at the time of the experiment. None had a background in German or any other V2-language.

Stimuli

A semi-artificial grammar, consisting of English words and German syntax, was used to generate the stimulus material for this experiment (see also Rebuschat & Williams, 2006). In creating the stimuli, English declarative sentences were rearranged in accordance with German syntax as in the examples below (1-3). In comparison to the finite-state grammars commonly employed in AGL research, this system has the advantage that (i) the grammatical complexity of natural languages is maintained and (ii) semantic information is present.

- (1) Simple sentence (one-clause construction)
 - a. English: Yesterday John bought the newspaper in the supermarket.

- b. German: Gestern kaufte John die Zeitung im Supermarkt.
- c. Stimulus: Yesterday bought John the newspaper in the supermarket.

(2) Complex sentence (two-clause construction; sequence: main-subordinate)

- a. English: Last year Susan visited Melbourne because her daughter lived in Australia.
- b. German: Letztes Jahr besuchte Susan Melbourne, weil ihre Tochter in Australien lebte.
- c. Stimulus: Last year visited Susan Melbourne because her daughter in Australia lived.

(3) Complex sentence (two-clause construction; sequence: subordinate-main)

- a. English: Since his parents needed groceries, David purchased everything necessary.
- a. German: Weil seine Eltern Lebensmittel brauchten, kaufte David alles Notwendige ein.
- b. Stimulus: Since his parents groceries needed, purchased David everything necessary.

As is evident from the examples, the elements within phrase boundaries were left intact, while the specific ordering of the phrases was altered. In (1), for example, the verb phrase (VP) was moved from third position in the phrasal sequence to second. In (2), the VP of the main clause was moved to second position while the VP of the subordinate clause was placed in final position. Finally, in (3) the VP of the subordinate clause was moved to final position, whereas the VP of the main clause was shifted to first position.

The linguistic focus in this experiment was on three rules that determine the placement of VPs in the semi-artificial language. These rules, which are partially based on German syntax, stated that, depending on the type of clause (main vs. subordinate) and the type of clause sequence (main-subordinate vs. subordinate-main), finite verbs had to be placed either in first, second or final position in terms of the phrasal sequence. Table 1 illustrates the three rules in question.

Rules V2 and V1 both applied to main clauses. They differed in that the former rule applied to main clauses that were not preceded by a subordinate clause and the latter to main clauses were preceded by a subordinate clause. In contrast, rule VF only applied to subordinate clauses, irrespectively of whether a main clause preceded or followed.

A total of 180 sentences were drafted for this experiment. The sentences were read out by a male native speaker of British English, digitally recorded on a Sony Mini-Disc player (MZ-R700) and subsequently edited with sound processing software (Audacity, version 1.2.4). The stimulus sentences were divided into a training and a testing set.

Table 1: Descriptions of the verb placement rules. Examples are given in parentheses.

Rule	Description (<i>Example</i>)
V2	Finite verb placed in second phrasal position of main clauses that are not preceded by a subordinate clause (<i>In the evening ate Rose excellent dessert at a restaurant.</i>)
V1	Finite verb placed in first position in main clauses that are preceded by a subordinate clause (<i>Since his teacher criticism voiced, put Chris more effort into his homework.</i>)
VF	Finite verb placed in final position in all subordinate clauses. (<i>George repeated today that the movers his furniture scratched.</i>)

Training set The training set consisted of 120 sentences and was subdivided into 60 plausible constructions and 60 implausible ones. That is, half of the sentences were syntactically correct but expressed semantically implausible propositions. Plausible and implausible items were designed so that participants would have to process the entire auditory string before being able to judge its plausibility. In most instances, the final phrase of the sentence would reveal whether the sentence was plausible or not, and participants had to process the entire string until reaching their judgment.

In order to train the experimental group, 40 sentences were created for each verb placement rule. All sentences were in the past tense. The sentences below are examples of plausible and implausible constructions (4-5).

(4) Plausible constructions

- a. Chris entertained today his colleagues with an interesting performance.
- b. George repeated today that his students about their classes cared.
- c. Since his teacher criticism voiced, put Chris more effort into his homework.

(5) Implausible constructions

- a. ? Rose abandoned in the evening her cats on planet Venus.
- b. ? Kate confessed today that her horse the corridor murdered.
- c. ? After his wife a thief surprised, communicated George with the police banana.

Testing set The testing set consisted of 60 new sentences and was subdivided into 30 grammatical and 30 ungrammatical items. The grammatical sentences followed the same syntactic patterns as the training sentences (V2, V2-VF, VF-V1). The ungrammatical templates were similar

to the grammatical ones with the exception that the position of the VP was incorrect (*V1, *V3, *V4, *VF, *VF-V2, *V1-VF). Several restrictions applied to the lexicon of the testing set. With the exception of a limited number of function words, no words were repeated from the training set, making the test analogous to the transfer paradigm in AGL research (Reber, 1969). No verb was repeated from the training set.

A frequency analysis of the testing set indicated that the average sentence length was 11.1 words per sentence for grammatical items and 11.6 for ungrammatical items. There was no significant difference between training and testing sets with regard to sentence length, $F(1, 193) = .922, p > .05$, i.e. sentence length was not a reliable cue to grammaticality in the testing phase.

Procedure

Experimental participants were trained on the semi-artificial grammar under incidental learning conditions by means of elicited imitations and plausibility judgments. Specifically, the training task required participants to listen to the training set on an item-by-item basis, to repeat each sentence after a delayed prompt (1,500 ms), and to judge whether the statement made was semantically plausible or not. The experiment began with a short practice session to familiarize participants with the training task. This consisted of four practice sentences which were not repeated in the actual training phase. No mention was made that the scrambling followed the word order rules of a natural language. The training sentences were presented to each participant in random order. The entire training phase took, on average, 40 minutes to complete. Controls did not receive any training.

After training, experimental participants were informed that the word order in the previous sentences was not arbitrary but that it followed a “complex system” instead. They were then instructed to listen to 60 new scrambled sentences, only half of which would follow the same rule-system as the sequences they had just been exposed to. Those sentences that did obey the rules should be endorsed as “grammatical” and those that did not rejected as “ungrammatical.” For each test sentence, participants were required to decide on its grammaticality, to report how confident they were in their judgment (*guess, somewhat confident, very confident*), and to indicate what the basis of their judgment was (*guess, intuition, memory, rule knowledge*). In the case of the control group, participants were merely told that they would listen to 60 scrambled sentences and asked to judge whether or not a sentence was grammatical. Participants were given no feedback regarding the accuracy of their grammaticality decisions.

The test sentences were presented to each participant in random order. The testing phase began with a short practice session to familiarize the participants with the new task. This consisted of four practice trials which were not repeated in the actual testing set. The entire testing phase took approximately 15 minutes to complete. All tasks were

run on a Dell PC (Windows XP) and delivered via Cedrus SuperLab Pro (version 2.0).

At the end of the experiment, all participants were given a debriefing questionnaire which prompted them to verbalize any rule or regularity they might have noticed during the course of the experiment. Finally, the questionnaire also asked participants to supply their name, age, gender, nationality, occupation and linguistic background.

Results

Performance on the grammaticality judgment task served as the measure of learning. Awareness was measured by means of verbal reports, confidence ratings and source attributions (Dienes & Scott, 2005).

Grammaticality judgments

The analysis of the grammaticality judgments showed that the experimental group classified 61.6% ($SD = 8.3\%$) of the test items correctly and the control group 42.9% ($SD = 5.1\%$). The difference between the two groups was significant, $t(27) = 7.289, p < .001$. Further analysis showed that the experimental group performed significantly above chance on this task, $t(13) = 5.150, p < .001$, while the controls scored significantly below chance, $t(14) = -5.361, p < .001$. That is, the training phase produced a clear learning effect in the experimental group.

Further analysis showed that the experimental group endorsed 71% ($SD = 13.5\%$) of all grammatical sentences and 47% ($SD = 19.7\%$) of all ungrammatical ones, $t(13) = 5.294, p < .0005$. The control group only endorsed 36.4% ($SD = 30.3\%$) of grammatical sentences and 51% ($SD = 28.4\%$) of ungrammatical ones, $t(14) = -5.268, p < .0005$. The difference between experimental and control subjects on grammatical items was significant, $F(1, 27) = 14.824, p < .001$, i.e. the experimental group was significantly more likely to correctly endorse grammatical strings. The difference between groups on ungrammatical strings was not significant, however, $F(1, 27) = .125, p > .05$. That is, the classification performance of the experimental groups was largely driven by the correct endorsement of grammatical items.

Confidence ratings

The following analyses only report the results of the experimental group. In terms of proportion, experimental participants tended to select the option “somewhat confident” most frequently (54%), followed by “very confident” (34%) and the “guess” option least frequently (12%). In terms of accuracy, the analysis indicated that experimental participants were most accurate when reporting to be very confident in their decisions (65%) and slightly less accurate when reporting to be somewhat confident (60%). Accuracy was lowest for those grammaticality decisions in which subjects had no confidence whatsoever (53%). Experimental participants scored significantly above chance when reporting to be somewhat confident and very confident, $p < .05$. When

participants reported to be guessing, performance was indistinguishable from chance. The guessing criterion for unconscious judgment knowledge was thus not satisfied.

The Chan-difference score (Dienes et al., 1995) was computed in order to establish whether learning in the experimental group was implicit by the zero correlation criterion. The average confidence for correct grammaticality decisions was 6.1 ($SD = 1.6$) and the average confidence for incorrect decisions was 5.6 ($SD = 1.7$), i.e. experimental participants were more confident in correct decisions than in incorrect ones. The difference (0.5) was significant, $t(13) = 2.310$, $p < .05$. That is, there was conscious judgment knowledge according to the zero correlation criterion. Participants were partially aware that they had acquired some knowledge during the training phase.

Source attributions

In terms of proportion, experimental participants most frequently believed their classification decisions to be based on rule knowledge (43%), followed by intuition (32%) and memory (15%). The guess category was selected least frequently (10%). In terms of accuracy, experimental participants scored highest when reporting to use rule knowledge (65%) to guide their decisions, followed by the intuition (59%) and memory (57%) categories. Subjects were least accurate when basing decisions on guesses (56%). Participants performed significantly above chance when basing their decisions on rule knowledge, $p < .001$, or on intuition, $p < .05$. The latter suggests that participants acquired at least some unconscious structural knowledge.

Verbal reports

The analysis of the verbal reports showed that, while most participants in this experiment were able to verbalize knowledge, there were no verbalizations that were relevant to the rules of the semi-artificial grammar. No subject was able to provide descriptions of the verb placement rules employed to generate the stimulus material or to provide correct examples of grammatical sentences. The analysis of the verbal reports further suggests that participants focused exclusively on the ordering of words within clauses, disregarding important cues such as clause type and clause sequence. This might be taken as an indication that participants did not pay attention to phrasal arrangements above the clause-level. Despite the fact that subjects were conscious of some knowledge, the analysis of the verbal reports suggests that subjects were largely unaware of the rules that determine the placement of VPs.

Discussion

The results of the experiment indicate that adult learners are able to acquire new syntactic knowledge under incidental learning conditions, while processing sentences for meaning, without the benefit of corrective feedback and after a relatively brief exposure period. The results also show that learners are able to transfer knowledge to stimuli

with the same underlying structure but new surface features, which suggests that an abstract representation has been derived from the original training sentences.

Although a clear learning effect was observed, the results also showed that learning was somewhat limited. For example, closer analysis of the grammaticality judgments showed that performance was largely driven by the above-chance endorsement of grammatical items. Experimental participants endorsed 71% of all grammatical sentences but also 47% of ungrammatical ones, which indicates that their classifications could have been partially based on memory for previously encountered patterns. If a test stimulus matched a training pattern, as was the case with the grammatical test sequences, subjects were likely to endorse it. However, when a test stimulus did not resemble a training pattern, subjects had to rely on guessing.

The fact that classification performance was not categorical, but probabilistic, in nature further suggests that subjects did not acquire linguistic rules. The acquisition of the rule-system employed to generate the stimuli would have resulted in the capacity of distinguishing grammatical and ungrammatical strings categorically. In this experiment, for example, subjects should have been able to endorse or reject a sentence purely on the basis of the placement of the verb: if the VP occupied the appropriate position, a sentence should have been endorsed; if it did not, the sentence should have been rejected. This would have resulted in high endorsement rates for grammatical stimuli and low endorsement rates for ungrammatical stimuli. The analysis of the grammaticality judgments in this experiment showed that this was not the case. When participants believed their classifications to be based on rule knowledge, this did not correspond to the word order rules of the semi-artificial grammar. The analysis of the verbal reports further supports this view.

Several reasons might explain why there was limited learning in this experiment. Firstly, subjects might simply have received an insufficient amount of exposure for learning to take place. The training phase consisted of 120 sentences conforming to the semi-artificial grammar and lasted approximately 40 minutes. Although some AGL experiments report learning effects after considerably briefer exposure periods, it is likely that subjects in natural language experiments require additional exposure. In contrast to AGL subjects, participants in this experiment possessed a rule-system that might have interfered with the grammar to be acquired. Considering the persistence of native language transfer errors in second language acquisition, it seems natural that prolonged stimulus exposure might be required. Secondly, participants' metalinguistic knowledge might have distracted their attention from relevant verb placement cues. The pre-existing knowledge of categories such as "subject", "verb" and "object" might aid acquisition by increasing the likelihood that subjects will notice these elements in the input. On the other hand, it might also distract them from paying attention to linguistic notions which they do not have

as readily available (such as clause type). It could also be that categories such as clause type or clause sequence are simply not perceived to be relevant elements of grammar and hence not noticed. It would be interesting to determine whether children without knowledge of linguistic terminology would perform differently on the experimental tasks.

In terms of awareness, the experiment provided evidence for the implicit learning of natural language structure. The analysis of confidence ratings and source attributions showed that, while subjects were aware of having acquired knowledge, they were at least partially unaware of what knowledge they had acquired. When attributing grammaticality judgments to intuition, subjects performed significantly above chance, i.e. they had acquired unconscious structural knowledge. At the same time, it is important to highlight that experimental subjects were significantly more accurate when reporting higher levels of confidence and when basing their decisions on explicit categories (memory and rule). Conscious but, judging from the debriefings, unverbalizable knowledge was clearly linked to improved performance in the grammaticality judgment task. The experiment thus mirrored the process of language acquisition outside the lab.

As far as methodology is concerned, the experiment further confirms that the sole reliance on verbal reports is clearly inadequate in order to assess awareness. The analysis of the verbal reports showed that participants were unable to verbally describe the rules of the semi-artificial system, which would have supported the erroneous assumption that there was no conscious knowledge in the experimental group. The fact that subjects developed conscious judgment knowledge would have gone unnoticed. The combined use of confidence ratings and source attributions appears to be a promising method for assessing awareness in language acquisition research.

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