Chapter 4

Intentional artificial grammar learning: when does it work?

Abstract

Actively searching for the rules of an artificial grammar has often been shown to produce no more knowledge than memorizing exemplars without knowing that they have been generated by a grammar. The present study investigated whether this ineffectiveness of intentional learning could be overcome by removing dual task demands and providing participants with more specific instructions. The results only showed a positive effect of learning intentionally for participants specifically instructed to find out which letters are allowed to follow each other. These participants were also unaffected by a salient feature. In contrast, for participants who did not know what kind of structure to expect, intentional learning was not more effective than incidental learning and knowledge acquisition was guided by salience.

Introduction

Numerous implicit learning studies have shown that complex patterns in the environment can be learned without the intention to do so. For example, participants in a serial reaction time (SRT) experiment, who are presented with a stimulus appearing at one of several locations on a computer screen, become faster at pressing the key corresponding to its location for trials on which the stimulus follows a regular sequence than for trials on which it does not. Similarly, in the artificial grammar learning (AGL) paradigm, participants who memorize a set of letter strings that—unknown to them—have been generated by an artificial grammar are subsequently able to judge the grammaticality of new letter strings. (See Seger (1994) for an extensive review of implicit learning paradigms.)

Nevertheless, several studies have indicated that performance on such tasks is enhanced if the standard procedure is preceded by a full explanation of the structure governing the stimulus domain. An early demonstration was provided by Danks and Gans (1975) using paired-associate learning with colored shapes and numbers as stimuli. At the beginning of the experiment, one half of the participants was briefly presented with a matrix for composing numbers from a digit corresponding to a color
and a digit corresponding to a shape. When presented with pairs of colored shapes and numbers, these participants learned the associations more quickly than uninformed participants. In addition, they were better at providing numbers for new colored shapes. Reber, Kassin, Lewis and Cantor (1980) showed that presenting participants with a schematic representation of an artificial grammar and explaining how it generates letter strings before showing the exemplars in the induction phase led to a higher percentage of correct grammaticality judgments. Recently, Destrebecqz (2004) demonstrated that participants in an SRT-task who had first learned the sequence explicitly had shorter reaction times than participants who had been presented with the sequence only briefly before the task.

The finding that participants benefit from an explanation of the structure prior to stimulus presentation suggests that, in absence of such an explanation, actively searching for patterns in the stimuli would be a useful strategy. However, it is a robust finding in artificial grammar learning that participants who are instructed to look for the rules underlying letter strings in order to facilitate their memorize task fail to do better on the grammaticality judgment test than uninformed participants (Dienes, Broadbent & Berry, 1991; Dulaney, Carlson & Dewey, 1984; Mathews, Buss, Stanley, Blanchard-Fields, Cho & Druhan, 1989; Perruchet & Pacteau, 1990; Reber, 1976; Shanks, Johnstone & Staggs, 1997). This surprising finding, that participants who actively try to discover a structure do not acquire more knowledge about it than participants who do not even know it is there, has been ascribed to various factors. Most explanations focus on the type of grammar, the opportunity to formulate incorrect hypotheses or the task load in the intentional condition.

Evidence for an effect of the type of grammar on incidental and intentional learning has been provided by studies comparing traditional (transitional) grammars with biconditional grammars. For biconditional grammars, intentional learning produces more knowledge of the structure than incidental learning, suggesting that the ineffectiveness of looking for rules depends on properties of the transitional grammar (Mathews et al., 1989; Shanks et al., 1997). Mathews et al. (1989) proposed that the patterns of family resemblance across exemplars generated by a transitional grammar may be abstracted so efficiently by an implicit learning mechanism that an explicit mechanism operating in parallel has a small chance of finding a pattern that has not been acquired implicitly. Furthermore, intentional learning may be hampered, because
transitional grammars contain more rules than can be held in working memory (Shanks et al., 1997).

The chances of acquiring the patterns generated by a transitional grammar may be further diminished by the relatively vague instructions provided to participants in the intentional condition. It has often been noted that these participants tend to formulate rules that are not representative of the grammar (e.g. Mathews et al., 1989; Reber, 1976; Reber et al., 1980; Shanks et al., 1997). In addition, guiding participants to look for the right kind of rules has been shown to enhance intentional learning. Danks and Gans (1975) found that participants, who had to memorize pairs of numbers and colored shapes, did not benefit from the general instruction to look for the underlying rules. A more specific instruction to look for rules that associate individual digits with colors and shapes, however, improved performance as much as actually teaching participants these associations. Similarly, when exemplars following the same pattern were presented together in the induction phase of an AGL-experiment, salience ensured that participants looked for the right kind of rules and intentional learning was more successful than incidental learning (Reber et al., 1980).

Finally, the standard intentional instruction used in AGL-experiments is not only relatively vague, but also of a dual nature. Participants are usually instructed to look for rules in addition to memorizing exemplars, which makes their task quite demanding. As noted by Mathews et al. (1989), participants in the intentional condition may easily be discouraged from looking for hard to find rules and restrict their activities to memorizing. So, the finding that the instruction to look for rules does not enhance learning may reflect that participants simply ignore it. Omitting the memorize task from the intentional condition may increase the likelihood that they continue to look for rules.

The present study evaluated the contributions of vague instructions and dual task demands to the ineffectiveness of intentional artificial grammar learning. Specifically, we investigated whether removing the memorize task from the intentional condition and instructing participants to look for specific rules would enable them to acquire more knowledge about the grammar by learning intentionally than by learning incidentally. In addition, it was explored whether these effects were different for salient and non-salient materials, as salience has been found to affect intentional and incidental learning in different ways (Reber et al., 1980; Turner & Fischler, 1993).
In a previous study (reported in Chapter 3), we presented participants with exemplars from two artificial grammars and instructed them to memorize each exemplar and the side of the screen where it appeared. For some participants, the exemplars contained a salient feature that was highly useful to this task. These participants only learned the feature. Participants presented with exemplars without a salient feature, in contrast, learned the structure of the two grammars. In the present study, this design will be used to investigate whether salience influences the effectiveness of the instructions to memorize, to look for rules and to look for specific rules.

Method

Participants. Forty-eight students from Leiden University (13 male, 35 female; 17-29 years of age, M = 20.07, SD = 2.87) participated in this experiment for payment.

Materials. The stimuli were generated by the four artificial grammars shown in Figure 1, based on Whittlesea & Dorken (1993). Each grammar generated 56 exemplars of seven or ten letters. The exemplars from grammars A1 and B1 formed the stimulus set with a salient feature (the constant first letter in grammar A); the exemplars from grammars A2 and B2 formed the stimulus set without a salient feature. Each set was divided into 64 induction stimuli and 48 test stimuli, so that both groups consisted of an equal number of exemplars from grammars A and B (see Appendix B). One half of the test stimuli, balanced for grammar and length, was presented as ‘complete exemplars’. The other half was presented as ‘fragments’, created by replacing the first letter of the exemplar by an underscore.

Design. The experiment consisted of an induction phase and a test phase. The dependent variable was the proportion of exemplars classified correctly at test. There were three independent variables. Firstly, the instruction in the induction phase was varied between participants. Sixteen participants were instructed to memorize which exemplars belonged to the left group and which belonged to the right group (memorize). Sixteen participants were instructed to look for the rules governing the exemplars on the left and the exemplars on the right (look for rules). Sixteen participants were instructed to look for the rules determining which letters were allowed to follow each other in the left group and which letters were allowed to follow each other in the right group (look for specific rules).
Secondly, the stimulus set was varied between participants. One half of the participants worked with materials with a salient feature and the other half worked with materials without a salient feature. For each participant, exemplars from grammar A were always presented on one side of the screen in the induction phase and exemplars from grammar B on the other. The location of the grammars (left or right) was balanced over participants. The order of presentation of the exemplars was randomized.

Finally, type of exemplar was varied within-subjects. All participants classified both complete exemplars and fragments presented in randomized order at test. Knowledge of the letter sequences would allow for accurate performance on both complete exemplars and fragments, while knowledge of the salient feature would only allow for accurate performance on complete exemplars.

Figure 1. The artificial grammars used to generate the stimuli (based on Whittlesea & Dorken, 1993).
**Procedure.** At the beginning of the induction phase, participants were informed that they would be presented with two groups of exemplars: one appearing on the left side of the computer screen and one appearing on the right. They received one of three instructions (memorize, look for rules, or look for specific rules). On each trial, an exemplar appeared on one side of the screen. Participants performed the instruction and typed in the letters of the exemplar. When they pressed the last key, their input was displayed underneath the original exemplar and a reminder of their instruction appeared. After the induction phase, all participants were informed that they would be presented with both complete exemplars and fragments of exemplars in the test phase. They were told that the stimuli would appear in the middle of the screen and that half belonged to the left and half belonged to the right group. They were required to indicate for each exemplar to which group it belonged by pressing either the left or right arrow on the keyboard. The experiment took about 25 minutes.

**Results**

A 2-between, 1-within mixed model analysis of variance (ANOVA) on the proportion of correct classifications showed a main effect of type of exemplar \( (F(1,42) = 6.156, p = .017) \), two-way interactions between stimulus set and type of exemplar \( (F(1,42) = 12.628, p = .001) \) and between stimulus set and instruction \( (F(2,42) = 4.034, p = .025) \) and a three-way interaction of stimulus set, instruction and type of exemplar \( (F(2,42) = 3.560, p = .037) \), which is illustrated by Figure 2.

As intentional and incidental learning were expected to be differentially affected by salience, we first examined the contribution of stimulus set to the three-way interaction. For the stimulus set without a simple feature, the ANOVA did not show a two-way interaction; there was an effect of instruction \( (F(2,21) = 4.573, p = .022) \) regardless of the type of exemplar. Post hoc tests with Bonferroni-correction indicated that participants who had looked for specific rules \( (M = .753, SD = .186) \) performed better on the classification test than participants who had looked for (unspecified) rules \( (M = .565, SD = .068, p = .046) \) and participants who had memorized exemplars \( (M = .568, SD = .144, p = .050) \). For the latter, performance was neither significantly different from chance, nor from performance by participants who had looked for (unspecified) rules. Participants who had looked for either unspecified or specific rules performed above chance \( (t(7) = 2.703, p = .031 \) and \( t(7) = 3.838, p = .006 \) respectively).
For the stimulus set with a salient feature, the ANOVA showed a significant interaction between instruction and type of exemplar ($F(2,21) = 3.699, p = .042$). Paired-samples t-tests for each instruction in this condition showed that more complete exemplars ($M = .829, SD = .216$) than fragments ($M = .528, SD = .129$) were classified correctly by participants who had been instructed to memorize ($t(7) = 2.621, p = .034$). One sample t-tests indicated that their performance was only above chance for complete exemplars ($t(7) = 4.312, p = .004$). Similarly, participants who had looked for (unspecified) rules were better at classifying complete exemplars ($M = .684, SD = .176$) than fragments ($M = .501, SD = .099, t(7) = 4.691, p = .002$) and performance was only above chance for complete exemplars ($t(7) = 2.949, p = .021$). For participants who had looked for specific rules, however, there was no difference between complete exemplars ($M = .604, SD = .204$) and fragments ($M = .616, SD = .111, t(7) = -.156, p = .872$); their overall performance was above chance ($t(7) = 2.460, p = .043$).

![Figure 2](image.png)

Figure 2. Mean proportions of complete exemplars and fragments classified correctly for each instruction and stimulus set with 95% confidence intervals.
Discussion

In previous studies, performance on structure sensitive tasks was shown to be enhanced by providing participants with an explanation of the structure governing the stimuli (Danks & Gans, 1975; Destrebecqz, 2004; Reber et al., 1980), but not by instructing participants to figure out the structure themselves (Dienes et al., 1991; Dulaney et al., 1984; Mathews et al., 1989; Perruchet & Pacteau, 1990; Reber, 1976; Shanks et al., 1997). The present study examined two characteristics of the ‘look for rules’- instruction typically used in AGL-experiments that may contribute to the observed ineffectiveness of intentional learning: dual task demands and a vague instruction.

With regard to dual task demands, the present experiment investigated whether intentional learning would produce more knowledge than incidental learning if participants in the intentional condition were relieved from the memorize task, enabling them to direct all their efforts to looking for rules. The results indicated that this was not the case; performance on the classification test by participants who had looked for (unspecified) rules could never be distinguished from performance by participants who had memorized exemplars. This finding is in line with a proposal by Cho and Mathews (1996), that participants who have to discover rules that do not immediately stand out have a strong tendency to adopt a strategy of memorizing exemplars in the hope of noticing regularities later. So, the ineffectiveness of intentional learning cannot be explained by the common requirement to perform both activities.

Vague instructions, however, made intentional artificial grammar learning less effective than it could be. Participants who looked for unspecified rules failed to acquire more knowledge of the grammar than participants who memorized exemplars without being informed that there were any rules. In contrast, participants who were specifically instructed to figure out which letters were allowed to follow each other did better on the classification test than participants who had learned incidentally. This shows that, at least for non-salient materials, the ineffectiveness of intentional artificial grammar learning can be overcome by specifying the kind of rules participants have to look for.

The vagueness of the traditional instruction to look for rules may particularly reduce the effectiveness of intentional learning with regard to transitional grammars. Indeed, Reber (1976) introduced these grammars precisely because people do not
expect the kind of rules they consist of. In the present study, the specific instruction to look for rules determining which letters are allowed to follow each other may have produced more accurate expectations. Several researchers have claimed that memorizing exemplars from an artificial grammar results in knowledge of specific letter chunks rather than of abstract rules (Dulaney et al., 1984; Kinder & Assmann, 2000; Perruchet & Pacteau, 1990).

The results of the present study are in contrast with two other explanations for the finding that transitional grammars are hard to learn intentionally. Mathews et al. (1989) suggested that intentional learning is obscured by the efficiency of implicit learning for this kind of structure. Shanks et al. (1997) suggested that looking for the rules of a transitional grammar is difficult, because the number of rules it consists of exceeds working memory capacity. Neither of these explanations can account for the finding that intentional learning was more effective than incidental learning when participants looked for specific rules.

A second question addressed by the present study was whether incidental and intentional learning would be differentially affected by salience. The results showed that the knowledge acquired by participants looking for specific rules was qualitatively different from the knowledge acquired by participants in the other conditions. Participants who had looked for specific rules were not affected by the salient feature. They were able to classify both complete exemplars and fragments, indicating that they had learned about the rules of letter order, which they had been instructed to look for. In contrast, participants instructed to memorize and participants instructed to look for unspecified rules, who presumably adopted a memorization strategy, had only acquired knowledge of the salient feature.

The pattern of results for the memorize group was the same as in Experiment 1 of our previous study. Subsequent experiments varying salience and usefulness have suggested that usefulness of the feature was responsible for blocking the learning of letter sequences. Salience probably enhanced acquisition of the feature (Chapter 3). Similarly, Whittlesea and Wright (1997) concluded from their Experiment 3 that salient repetitions enhanced acquisition of that characteristic. In line with these findings, the present experiment indicated that learning is guided by salience, unless one knows what kind of pattern to look for.

In conclusion, the present study suggests that the ineffectiveness of intentional artificial grammar learning observed in previous studies may in part have been due to
vague instructions, but not to dual task demands. Allowing participants to direct their efforts at looking for rules without having to memorize exemplars did not make intentional learning easier. Only providing participants with specific instructions enabled them to intentionally learn the rules of the artificial grammars. If one knows what kind of rules to look for, the intention to learn about an artificial grammar increases knowledge acquisition from presentation with grammatical exemplars. In addition, looking for a specific kind of structure diminishes one’s sensitivity to salient features in the environment, which guide knowledge acquisition if one does not know what kind of structure to expect.