Implicit artificial grammar learning: effects of complexity and usefulness of the structure

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Chapter 1

Introduction

People often make intentional efforts to acquire skills or knowledge and are generally aware of what they learn from these attempts. However, one can also become sensitive to a structure in the environment by simply dealing with instances of the pattern. This implicit way of learning is usually described as a process that occurs unintentionally and results in knowledge of which one is not fully aware (see reviews by Reber, 1989 and Seger, 1994). It has been suggested that implicit learning is involved in the acquisition of complex patterns, such as motor skills (Seger, 1994), social rules (Reber & Allen, 2000; Seger, 1994) and the grammars of natural languages (Ellis, 2005; Reber & Allen, 2000; Perruchet & Pacton, 2006; Saffran, Newport, Aslin, Tunick & Barrueco, 1997).

Many studies have been concerned with establishing characteristics that distinguish implicit learning from explicit hypothesis testing. It is generally agreed that implicit learning can be defined as unintentional knowledge acquisition (Frensch, 1998). Further proposals to distinguish between implicit and explicit learning, however, have raised three major controversies in the field. Firstly, there is an ongoing dispute on whether implicit learning leads to knowledge of which one is not aware. Secondly, the type of knowledge acquired in implicit learning is under debate. Thirdly, there are different views on how the process itself should be characterized. After a brief description of two paradigms used to study implicit learning, these issues will be discussed. The present thesis is mainly concerned with characterizing the implicit learning process.

Research paradigms

At present, implicit learning is mainly investigated using two experimental paradigms: Artificial Grammar Learning (AGL; Reber, 1967) and the Serial Reaction Time (SRT) task (Nissen & Bullemer, 1987). In the induction phase of an AGL-experiment, participants are typically instructed to memorize meaningless strings of letters (e.g. ZTPRJ). At the beginning of the test phase, they are informed that the letter strings had been generated by an artificial grammar (see Figure 1 on page 2 for an example of an artificial grammar). Participants are instructed to judge whether or not new exemplars have been generated by the same grammar as the previous exemplars. Knowledge of the grammar is indicated by above chance discrimination between grammatical (e.g. ZTPQN) and ungrammatical exemplars (e.g. ZTQPN).

Participants in an SRT-task have to respond to a stimulus appearing in one of several locations on a computer screen by pressing the key corresponding to that location. Unknown to the participants, the stimulus follows a regular sequence of locations on most trials. Implicit learning is evidenced by participants' reaction times, which decrease for stimuli that obey the sequence of locations as compared to stimuli that violate it.

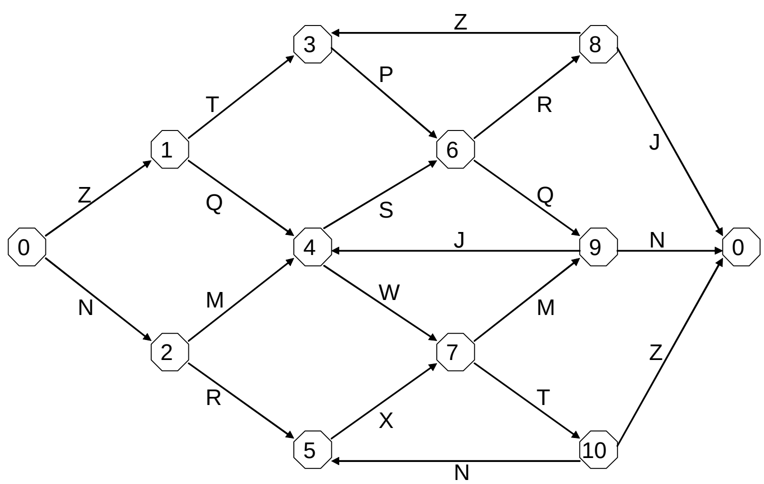

Figure 1. An example of an artificial grammar. Exemplars are generated by following the arrows from the initial state (left 0) to the end state (right 0), while adding the letter associated with each arrow to the string.

Implicit versus explicit knowledge

The first studies on implicit learning asked participants to report verbally what they had learned. As these verbal reports were insufficient to explain performance, it was concluded that the acquired knowledge was not completely accessible to consciousness (Reber, 1989). Shanks and St. John (1994), however, argued that verbal reports are insensitive; they may not have elicited all of the participants' knowledge. In addition, the questions participants had to answer may have been designed to measure one kind of knowledge, expected by the experimenter, while participants acquired another type of knowledge.

Shanks and St. John (1994) proposed that knowledge can be called implicit if it is demonstrated on a performance test, but not on an equally sensitive test that directly probes the same information. For example, participants in an AGL-task would have implicit knowledge if they scored above chance on a grammaticality judgment test, but not on a recognition test for (fragments of) exemplars from the induction phase. Similarly, participants in an SRT-task would have implicit knowledge if they responded increasingly faster to stimuli occurring at locations specified by the sequence, but were unable to indicate where the next stimulus would appear on a prediction test. Many AGL and SRT-studies have accepted this suggestion and incorporated recognition and prediction tests. The results generally indicated that the acquired knowledge was explicit (see reviews by Dienes & Berry, 1997 and Shanks & St. John, 1994).

However, it could be argued that tasks can seldom be considered pure measures of single processes. Recognition and prediction tests may be sensitive to implicit as well as explicit knowledge, resulting in an overestimation of participants' awareness (Jacoby, 1991; Reber, Allen & Regan, 1985, Shanks & St. John, 1994). To circumvent the assumption of process purity, Jacoby (1991) developed a process dissociation framework to estimate the relative contributions of controlled and automatic influences of memory to a task. In this framework, a condition in which both controlled and automatic influences facilitate performance is compared with a condition in which controlled influences facilitate, but automatic influences hamper performance. Process dissociation procedures have been used in a few implicit learning studies. Some demonstrated that participants could control their implicitly acquired knowledge (Dienes, Altmann, Kwan & Goode, 1995; Shanks, Rowland & Ranger, 2005), while others also found some evidence of automatic knowledge application (Destrebecqz & Cleeremans, 2001; Higham, Vokey & Pritchard, 2000).

Another response to the finding that implicitly acquired knowledge is accessible to direct tests has been that this knowledge may nevertheless be implicit in the subjective sense that people are unaware of possessing it (Dienes & Berry, 1997). Two criteria for the absence of meta-knowledge have been proposed. According to the guessing criterion, people lack meta-knowledge when they perform above chance while they think they are guessing. According to the zero-correlation criterion, people lack meta-knowledge if their confidence ratings are uncorrelated with accuracy (Dienes et al., 1995). The former may be the better criterion. Knowledge classified as explicit according to the guessing criterion was affected by divided attention, whereas knowledge classified as implicit was not. With the zero-correlation criterion, this dissociation was not obtained (Dienes et al., 1995). In addition, the sensitivity of the zero-correlation criterion has been shown to depend on the type of confidence scale used (Tunney & Shanks, 2003). Although more research on subjective measures is needed, Marescaux, Izaute and Chambres (2002) concluded from their literature review that implicit learning often leads to knowledge that is not accompanied by meta-knowledge.

In conclusion, although it is generally acknowledged that explicit knowledge is a common result of implicit learning (Cleeremans & Jimenez, 1998; Reber, 1989; Seger, 1994), the process may, in addition, acquire implicit knowledge in the sense that it is automatically applied or that it is not accompanied by meta-knowledge.

What is learned in implicit learning?

The second major question in the field of implicit learning concerns the type of information people acquire. Reber (1989) originally proposed that implicit learning automatically leads to an abstract mental representation of covariation patterns in the environment. In AGL, participants have been shown to acquire abstract knowledge about the grammar, like legal patterns of repetitions within exemplars (Gomez, Gerken & Schvaneveld, 2000; Tunney & Altmann, 2001). However, participants have also been shown to retain knowledge of the unique exemplars they were presented with. Their grammaticality judgments were not only affected by an exemplar's grammaticality, but also by its similarity to individual exemplars shown in the induction phase (Brooks & Vokey, 1991; Vokey & Brooks, 1992).

Furthermore, participants generally learn fragments of exemplars. In one study, memorizing bigrams (two-letter-fragments) and memorizing whole exemplars led to similar performance on a grammaticality judgment test (Perruchet & Pacteau, 1990). However, studies equating the familiarity of bigrams and trigrams for grammatical and ungrammatical exemplars have shown a residual effect of grammaticality on participants' judgments. This indicates that fragment knowledge, like knowledge of abstract regularities and of whole exemplars, does not by itself explain performance (Higham, 1997; Knowlton & Squire, 1996; Meulemans & Van der Linden, 2003).

In SRT-tasks, participants generally seem to learn the (conditional) probabilities of the locations where the stimulus appears (Cleeremans & Jimenez, 1998; Stadler, 1992). However, presentation with a deterministic sequence may, in addition, lead to knowledge of the exact sequence or parts of it (Cleeremans & Jimenez, 1998). In short, results from both paradigms suggest that implicit learning does not necessarily lead to one type of knowledge. Participants may acquire abstract regularities as well as (fragments) of exemplars.

Characteristics of the implicit learning process

A third issue, central to the present thesis, is how the process of implicit learning can be characterized. Introduced as an alternative to explicit hypothesis testing, implicit learning was represented as an automatic abstraction process that occurs inevitably whenever people process structured stimuli (Reber, 1989). Implicit learning would be more robust with respect to disorders than explicit learning and invariant with age and IQ (Reber, 1992). In addition, it was proposed to store the frequency of co-occurrence of all events in the environment, whereas explicit learning would involve active selection of a small amount of relevant information (Hayes & Broadbent, 1988). In accordance with this view, implicit learning was claimed to be particularly suitable for complex structures (Reber, 1976).

Support for the automatic and unselective view of implicit learning was provided by studies demonstrating structure learning in the absence of any obvious reason to learn. For example, participants learned the words of an artificial language when they were presented as background sounds during a drawing task (Saffran et al., 1997). Similarly, the competitive chunking model (Servan-Schreiber & Anderson, 1990) was able to simulate artificial grammar learning as an automatic consequence of reading. In addition, participants instructed to look for the rules of an artificial grammar typically do not acquire more knowledge than participants who learn implicitly (Reber, 1989).

In contrast, Whittlesea and colleagues have characterized implicit learning as selective and accidental rather than ineluctable and unselective. They demonstrated that the knowledge acquired in implicit learning experiments depends both on the task participants perform (Whittlesea & Dorken, 1993) and on accidental characteristics of the stimuli, such as familiarity, salience (Whittlesea & Wright, 1997) and spatial organization (Wright & Whittlesea, 1998). According to their episodic processing account, sensitivity to a structure (at test) is due to overlap in information processing with earlier (learning) situations. In any situation, many accidental characteristics may guide attention and only attended information will be learned (Whittlesea & Wright, 1997; Wright & Whittlesea, 1998).

This thesis

The present thesis further investigated the issue of whether implicit learning is unselective and ineluctable or selective and accidental. First, implicit learning was shown to be hampered by increasing complexity of the structure, which suggests that the process does not unselectively and ineluctably abstract any structure in the environment. Subsequently, the selectivity of implicit learning was examined by exploring a suggestion that people selectively acquire the aspect of a structure that is most useful to their current task (Endo & Takeda, 2004). Continuing this line of reasoning, it was proposed that implicit learning is neither ineluctable nor accidental, but occurs whenever a structure is useful to one's current task.

Although the main aim of this thesis was to investigate the selectivity and predictability of the implicit learning process, the type of knowledge acquired in each study and its implicit or explicit nature were explored as well. In addition, the role of salience in implicit and explicit learning was discussed, as this turned out to be an influential factor in some of the experiments.

Outline of the thesis

Apart from the present introduction and a concluding chapter, this thesis contains six chapters reporting empirical work. The experiments were performed in the AGL-paradigm, because this easily allows varying the task in the induction phase. The empirical chapters are based on manuscripts that have been (or will be) submitted to international psychological journals. Fenna Poletiek is co-author to these manuscripts.

Chapter 2 investigated the prediction that implicit as opposed to explicit learning is unaffected by increasing complexity of the structure that has to be learned. The results showed that, although implicit learning was more successful than explicit learning, it was negatively affected by increasing complexity. The acquisition of second-order dependencies was particularly hampered. These findings are in contrast with the view that implicit learning is automatic and unselective.

Chapter 3 replicated a finding from the contextual cueing paradigm that implicit learning involves selecting the aspect of a structure that is most useful to one's current task (Endo & Takeda, 2004). In Experiment 1, participants implicitly learned a highly useful feature, while they did not acquire other aspects of the grammar. Experiment 2 showed that, although salience affected the participants' awareness of the feature, selection for implicit learning was based on usefulness.

Chapter 4 showed that explicit learning could be more successful than implicit learning when the typical instruction to look for unspecified rules was replaced by an instruction to find out which letters were allowed to follow each other. For participants who did not know what kind of structure to expect, explicit learning did not differ from implicit learning and knowledge acquisition was guided by salience.

Chapter 5 tested the hypothesis that implicit structure learning reliably occurs when the structure is useful to one's current task. The results of Experiments 1 and 2 were in line with this hypothesis and in contrast with the view that implicit learning occurs automatically. Experiment 3 provided evidence that implicit learning of useful structures can produce implicit knowledge in the sense that its application is difficult to control.

Chapter 6 generalized the finding that implicit learning occurs when the structure is useful to one's task in the induction phase, but not when it is useless from adults to children. However, although they learned under the same conditions as adults, 10 to 11-year-old children acquired less knowledge of the grammar, particularly about second-order dependencies.

Chapter 7 replicated the negative effect of complexity on implicit learning. Performance was enhanced by adding a semantic reference field. However, the reference field produced its effect by making letter chunks salient and caused learning to be explicit. Moreover, explicit learning in the presence of a reference field was as much affected by complexity as implicit learning.