Introduction: Implicit and explicit learning of languages

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Implicit learning, essentially the process of acquiring unconscious (implicit) knowledge, is a fundamental feature of human cognition (Cleeremans, Destrebecqz, & Boyer, 1998; Dienes, 2012; Perruchet, 2008; Shanks, 2005; Reber, 1993). Many complex behaviors, including language comprehension and production (Berry & Dienes, 1993; Winter & Reber, 1994), music cognition (Rohrmeier & Rebuschat, 2012), intuitive decision making (Plessner, Betsch, & Betsch, 2008), and social interaction (Lewicki, 1986), are thought to be largely dependent on implicit knowledge. The term *implicit learning* was first used by Arthur Reber (1967) to describe a process during which subjects acquire knowledge about a complex, rule-governed stimulus environment without intending to and without becoming aware of the knowledge they have acquired. In contrast, the term *explicit learning* refers to a process during which participants acquire conscious (explicit) knowledge; this is generally associated with intentional learning conditions, e.g., when participants are instructed to look for rules or patterns.

In his seminal study, Reber (1967) exposed subjects to letter sequences (e.g., TPTS, VXXVPS and TPTXXVS) by means of a memorization task. In experiment 1, subjects were presented with letter sequences and simply asked to commit them to memory. One group of subjects was given sequences that were generated by means of a finite-state grammar (Chomsky, 1956, 1957; Chomsky & Miller, 1958), while the other group received randomly

constructed sequences. The results showed that grammatical letter sequences were learned more rapidly than random letter sequences. Reber suggested that this memorization advantage reflected increasing sensitivity to grammatical structure in the former group. Experiment 2 consisted of two parts. In the first part of the experiment (the exposure phase), subjects were presented with letter sequences that had been generated by means of a finite-state grammar and simply instructed to memorize the sequences. Subjects were not told that the letter arrangement followed the rules of a grammar. In the second part of the experiment (the testing phase), subjects were informed that the previous letter sequences had been formed by a set of grammatical rules. Subjects were then given new letter sequences, only half of which followed the same grammar, and instructed to judge whether the sequences were grammatical or not. Reber (1967) found that subjects judged 79% of all letter sequences correctly, which indicated that simple memorization of grammatical strings was sufficient for subjects to derive information about the underlying grammar. Interestingly, when asked to verbalize the rules that generated the letter strings, subjects were unable to do so. In other words, subjects were able to acquire knowledge without intending to (they were not informed about the existence of the grammar, nor did they know they were going to be tested) and without becoming aware of the acquired knowledge (they were unable to verbalize rules or patterns). Reber (1967, p. 863) concludes that the “rudimentary inductive process” observed in the experiment was likely to be intrinsic in other processes, including language acquisition and pattern perception.

Despite ongoing debates about the nature of the acquired knowledge (How is it represented, and is it really unconscious?), the past decades have resulted in a relative consensus on various characteristics of implicit learning (Berry & Dienes, 1993; Cleeremans et al., 1998; Dienes & Berry, 1997). For example, Reber’s (1967) observation that subjects can rapidly acquire knowledge from a complex stimulus domain without intending to has

been frequently replicated (e.g., Dienes, Altmann, Gao, & Goode, 1995; Dienes & Scott, 2005; Tunney & Shanks, 2003).[1] It is clear that implicit learning can give rise to a sense of intuition, i.e. subjects often know that they have acquired knowledge but they are unaware of what that knowledge is (e.g., Dienes & Scott, 2005; Rebuschat, 2008; Rebuschat & Williams, 2006, 2012). Several studies have shown implicit knowledge to be more robust in the face of neurological disorder (e.g., Knowlton, Ramus, & Squire, 1992), and implicit knowledge might also be retained more easily and longer than explicit knowledge (Allen & Reber, 1980).

While implicit learning as a research strand in cognitive psychology began with the Artificial Grammar Learning (AGL) experiments conducted by Reber and colleagues (1967, 1969, 1976; Reber & Allan, 1978; Reber & Lewis, 1977; Reber & Millward, 1968, 1971), these were not the first studies to employ finite-state grammars to investigate aspects of human cognition, as Reber (1967) himself points out (e.g., Miller, 1958), nor where they the only ones. Roughly around the same time as Reber conducted his first studies on implicit learning, several researchers began using artificial systems in order to investigate language acquisition (e.g., Braine, 1963, 1966; Moeser & Bregman, 1972; Segal & Halwes, 1965, 1966; Smith, 1966). This separate strand of research emerged as a major line of inquiry within developmental psychology, and in its present guise of *statistical learning* (Saffran, Aslin, & Newport, 1996; Saffran, Newport, & Aslin, 1996) continues to be particularly productive (Misyak, Goldstein, & Christiansen, 2012; Gómez, 2007, Saffran, 2003).

Statistical learning, i.e. our ability to make use of distributional information in the input to bootstrap language acquisition, involves computations based on units or patterns (e.g., sounds, syllables, syntactic categories). Research in statistical learning often focuses on

[1] In fact, Reber (1967, Expt. 2) is so easily replicated that it can be used as an in-class demonstration in introductory psychology courses. Fellow Cambridge students will remember the in-class version of Reber (1967) developed by John Williams, in which students are asked to perform the grammaticality judgment task by snapping fingers to endorse grammatical sequences and slamming hands on the table to reject ungrammatical ones.

infant or child language acquisition, though studies with adult subjects are also common. Both lines of research, implicit learning and statistical learning, focus on how we acquire information from the environment and both rely heavily on the use of artificial systems. In typical experiments, subjects are initially exposed to stimuli generated by an artificial system and then tested to determine what they have learned. Given these and other similarities, Perruchet & Pacton (2006) argue that these distinct lines of research actually represent two approaches to a single phenomenon, and Conway & Christiansen (2006) propose combining the two in name: *implicit statistical learning* (see also Onnis, Destrebecqz, Christiansen, Chater, & Cleeremans, this volume; Perruchet & Poulin-Charronat, this volume; Walk & Conway, this volume).[2]

Research on implicit (statistical) learning is not restricted to the two research strands outlined above. The field of Second Language Acquisition (SLA), for example, has a long-standing interest in the topic of implicit and explicit learning (Andringa & Rebuschat, 2015; N. Ellis, 1994; Hulstijn & R. Ellis, 2005; Sanz & Leow, 2011; Williams & Rebuschat, forthcoming). In part, this interest was sparked by Krashen's (1977, 1979, 1981, 1994 and elsewhere) proposal that learners possess two independent ways of developing knowledge of a second language (L2). According to Krashen, language *acquisition* is an incidental process that results in tacit linguistic knowledge, while language *learning* is an intentional process that results in conscious, metalinguistic knowledge. In speech comprehension and production, learners are thought to rely exclusively on *acquired* (or implicit) knowledge. The role of *learnt* (or explicit) knowledge is to monitor utterances for mistakes. Importantly, Krashen claimed that there is no interface between explicit and implicit knowledge (see below). For example, explicit knowledge of a rule does not help the implicit acquisition of the same rule.

[2] For discussion of similarities and differences between implicit and statistical learning research, see Misyak, Goldstein, & Christiansen (2012), Perruchet and Pacton (2006), and Rebuschat (2008).

For these reasons, Krashen argued that language pedagogy should focus on creating the conditions for language *acquisition* to take place, as opposed to language *learning*.

Krashen's Monitor model generated considerable controversy (see Gregg, 1984; McLaughlin, 1978, for early critiques). But it was also responsible for the increased interest in the role of implicit and explicit learning/knowledge in L2 acquisition. The current situation can be summarized as follows: "(…) There is broad consensus that the acquisition of an L2 entails the development of implicit knowledge. However, there is no consensus on how this is achieved; nor is there consensus on the role played by explicit knowledge." (R. Ellis, 2005, p. 143) Over the past 25 years, three related questions have received considerable attention and yielded a substantial amount of empirical research. The first question concerns the role of awareness in language acquisition and the possibility of learning without awareness (e.g., Godfroid & Winke, this volume; Hama & Leow, 2010; Leow, 1997, 2000, this volume; Leow & Hama, 2013; Leung & Williams, 2011; Paciorek & Williams, this volume; Schmidt, 1990, 1995, 2001; Williams, 2005, 2009). The second question is methodological in nature and refers to the measurement of awareness. The focus here has been on how to measure awareness at the time of encoding, i.e. while participants are engaged on a learning task (e.g., Godfroid & Schmidtke, 2013; Leow, 1997; Leow, Grey, Marijuan, & Moorman, 2014), and awareness of what has been learned, i.e. of the product of learning (e.g., R. Ellis, 2005; Grey, Williams, & Rebuschat, 2014; Hamrick & Rebuschat, 2012; Rebuschat, 2013; Rebuschat, Hamrick, Sachs, Riestenberg, & Ziegler, in press). The third question concerns the *implicit-explicit interface*, i.e. the issue of whether explicit knowledge (e.g., in the form of taught pedagogical rules) can promote the development of implicit L2 knowledge (R. Ellis, this volume). Several theoretical positions have been proposed, ranging from Krashen's (1977, 1979, 1981) strong non-interface position to interface positions such as the one proposed by Robert DeKeyser (1997, 1998) (see N. Ellis, 2011, for review).

This volume: Three approaches, one phenomenon

The present volume brings together eminent researchers from distinct research traditions (implicit learning, statistical learning, SLA) who share a mutual interest in implicit and explicit learning but whose paths would not normally cross. It is not, however, the first volume to do so.[3] This collection was conceived as a 20-year follow-up to the seminal (and eponymous) volume edited by Nick Ellis in 1994, which pursued the same objective. Both volumes feature 18 contributions by researchers from a variety of disciplines, including cognitive psychology, linguistics, education, developmental psychology, and computer science. Both volumes cover a range of methodological approaches, and both present a wide variety of views, ranging from strongly empiricist accounts to nativist accounts. It is interesting to note the differences, too. For example, in N. Ellis (1994), three chapters approach the topic of the volume from a Chomskyan angle (Rutherford, 1994; Roberts, 1994; Cook, 1994), whereas in the current volume only one does. This could be seen as an indication that UG-based approaches have decreased in popularity, at least when it comes to the study of implicit and explicit L2 learning (though see VanPatten, 2011; VanPatten & Rothman, this volume, for important counterarguments). This is perhaps not surprising, since most research on implicit and statistical learning is generally empiricist in orientation (see Reber, 1993, 2011, for discussion). Another difference between the volumes concerns methodologies. Understandably, N. Ellis (1994) does not feature eye-movement research (Godfroid & Winke, this volume) or EEG/ERP research (Morgan-Short et al., this volume), simply because these methodologies were yet to make a major impact in the early 1990s.

Each chapter in this volume was peer-reviewed by anonymous reviewers and by the editor. The volume is divided into three parts. The first part contains ten chapters that offer a

[3] Nor will it be the last. The journal *Studies in Second Language Acquisition* is dedicating its June 2015 issue to the topic of implicit and explicit learning.

range of theoretical perspectives on issues related to the study of implicit and explicit learning. Nick Ellis focuses on the dynamic interactions of implicit *and* explicit language learning and usage, and Jan Hulstijn assesses advantages and disadvantages of the two-system view. Ron Leow's chapter discusses the operationalization of key concepts (such as awareness and implicit learning) and its implications for the interpretation of current research (e.g., Hama & Leow, 2010; Williams, 2005) and future studies. Albertyna Paciorek and John Williams then contribute a much-needed summary of recent research on semantic implicit learning, an area of language that has been significantly neglected in implicit learning studies. Bill VanPatten and Jason Rothman provide a generative outlook on the implicit-explicit debate. In contrast, Karen Roehr, in her chapter on the role of explicit knowledge, approaches the topic from a usage-based perspective of language. In their chapter, Pierre Perruchet and Bénédicte Poulin-Charronat describe insights from the implicit learning literature on the learnability of language, while Dan Weiss, Tim Poepsel and Chip Gerfen, coming from a statistical learning background, consider the challenges posed by multilingual environments to statistical learning accounts. The final two chapters of this section focus on implicit statistical learning (ISL). First, Anne Walk and Christopher Conway discuss the role of ISL in typical and atypical language development, then Luca Onnis, Arnaud Destrebecqz, Morten Christiansen, Nick Chater, and Axel Cleeremans offer a computational perspective on the implicit learning of non-adjacent dependencies.

The second part of the volume contains five chapters that review research paradigms or methods used to investigate implicit and explicit learning. Eleni Ziori and Emmanuel Pothos summarize current issues and debates in Artificial Grammar Learning (AGL) research, whereas John Rogers, Andrea Revesz and Patrick Rebuschat illustrate the challenges faced when validating a new artificial language. In the next chapter, Cristina Sanz and Sarah Grey examine the limitations of relying solely on accuracy data when investigating

what can and cannot be acquired under implicit and explicit learning conditions. They encourage researchers to incorporate online processing measures. These, in turn, are reviewed in detail in the next two chapters. First, Aline Godfroid and Paula Winke explain how eye-movement data can contribute to the study of implicit and explicit processes. Then, Kara Morgan-Short, Mandy Faretta-Stutenberg and Laura Bartlett-Hsu outline the potential contributions of event-related potential (ERP) research to issues in implicit and explicit L2 learning.

The final section focuses on practical applications, specifically on the case of instructed second language acquisition, one of the ideal real-world scenarios for testing theories about implicit and explicit learning. Ilina Kachinske, Peter Osthus, Katya Solovyeva, and Mike Long present the results of an experimental study on the implicit learning of L2 morphosyntax and evaluates its relevance for language teaching. Rod Ellis discusses recent research on form-focused instruction on the development of implicit and explicit L2 knowledge. Finally, Jaemyung Goo, Gisela Granena, Yucel Yilmaz, and Miguel Novella report the results of an extensive meta-analysis that investigated the relative effectiveness of implicit and explicit instruction.

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