Aligning implicit learning and statistical learning: Two approaches, one phenomenon

Patrick Rebuschat (p.rebuschat@lancaster.ac.uk)
Department of Linguistics and English Language
Lancaster University, Lancaster LA1 4YL, UK

Padraic Monaghan (p.monaghan@lancaster.ac.uk)
Department of Psychology
Lancaster University, Lancaster LA1 4YL, UK

Nathaniel D. Anderson (nandrsn3@illinois.edu)
Department of Psychology, University of Illinois at Urbana-Champaign, Champaign, IL 61820, USA

Christopher M. Conway (cconway@gsu.edu)
Department of Psychology, Georgia State University
Atlanta, GA 30303-3083, USA

Gary S. Dell (gdell@illinois.edu)
Department of Psychology, University of Illinois at Urbana-Champaign, Champaign, IL 61820, USA

Rebecca Gomez (rgomez@u.arizona.edu)
Department of Psychology
University of Arizona, Tucson AZ 85721, USA

Keywords: Implicit learning; statistical learning

Goals and Scope

The past 15-20 years have witnessed a particularly strong interest in our ability to rapidly extract structured information from the environment. This fundamental process of human cognition is widely believed to underpin many complex behaviors – from language development and social interaction to intuitive decision making and music cognition – so this interest spans practically all branches of cognitive science. Research on this topic can be found in two related, yet traditionally distinct research strands, namely "implicit learning" (Reber, 1967) and "statistical learning" (Saffran, Aslin, & Newport, 1996).

Both lines of research focus on how we acquire information from complex stimulus domains and both rely heavily on the use of artificial systems (e.g., finite-state grammars, pseudoword lexicons). In typical experiments, participants are initially exposed to stimuli generated by an artificial system and then tested to determine what they have learned. Given these and other significant similarities, Perruchet and Pacton (2006) argue that these distinct lines of research actually represent two approaches to a single phenomenon, and Conway and Christiansen (2006) propose combining the two in name: "implicit-statistical learning". Yet, despite frequent acknowledgements that researchers in implicit learning and statistical learning might essentially be looking at the same phenomenon, there is surprisingly little alignment between the two strands.

This symposium seeks to remedy this situation by bringing together leading researchers from both areas in order to promote a shared understanding of research questions and methodologies, to discuss similarities and differences between the two approaches, and to work towards a joint research agenda. The symposium comprises four presentations, followed by a thematic discussion, which provide coverage of these phenomena in terms of development (children and adults), different language learning tasks (sublexical phonotactics, word acquisition, grammar learning), and their role in both production and comprehension, each integrating multidisciplinary perspectives. Gomez focuses on implicit-statistical learning in early development, identifying words and grammatical sequences and the memory systems that underlie this learning. Monaghan and Rebuschat measure word learning and grammar learning in adults, while varying the knowledge that participants have of the structure they are acquiring. Dell and Anderson demonstrate how their work on acquisition of phonotactic constraints is exhibited in speakers' productions, and discuss the inter-relation in speech between implicit and statistical learning. Finally, Conway provides an overview of the two fields, and proposes a novel framework that unifies implicit learning and statistical learning.

The Contributions of Emerging Learning Systems to Implicit and Explicit Statistical Learning in Early Development (Gomez)

Here we propose that statistical learning changes qualitatively as a function of the different learning systems emerging across early development. Early in development, infants do not appear to retain veridical details of statistical learning. We argue that this stems from underdevelopment of the hippocampus, a structure well known for supporting the explicit episodic details of our experiences. Instead, very young infants rely on cortical learning which shows a gradual retention function requiring many exposures over time for consolidation in long-term memory. With increasing maturity in the second and third years of life the hippocampus begins to support rapid encoding and retention of details from learning, ensuring a stable initial memory trace and increased fidelity of memory. We argue that implicit, incremental cortical learning is advantageous in allowing infants to tune to fine details in their input while preventing retention of idiosyncratic patterns hippocampal learning would permit. By this view, the infant brain supports a very different profile of learning than is found in older learners with implications for theories of statistical and implicit learning.

A Single Paradigm for Implicit and Statistical Learning (Monaghan & Rebuschat)

There has been a traditional distinction in methods used to study implicit learning and statistical learning in language research. Implicit learning tended to address the unconscious compared to conscious knowledge of grammatical structures of sequences, whereas statistical learning manipulated the probabilities of sequences to measure the role of statistics in acquisition of words or simple local constraints in grammatical sequences. This distinction between grammatical structures and learning of words, or simpler sequences, has in turn been related to the operation of procedural and declarative memory systems. We have developed an experimental paradigm that enables simultaneous testing of both classic implicit learning paradigms and statistical learning of sequence structure. The paradigm involves artificial grammar sentences accompanying two dynamic scenes, one of which is described by the sentence. Through cross-situational learning, participants are able to determine the target scene. In a series of studies, we show that acquisition of both vocabulary and grammar is promoted by explicit information about the language structure, that awareness of structure affects acquisition during learning, but is not distinctive at the endpoint of learning, and furthermore that effective statistical learning facilitates explicit knowledge about the structure. We show that two traditions of learning – statistical and implicit – can be conjoined in a single paradigm to explore both the phenomenological and learning consequences of statistical structural knowledge.

Implicit Learning of Phonotactic Distributions in Language Production (Dell & Anderson)

The statistical patterning of linguistic elements is implicitly learned from experience. This is as much true when this experience involves production as when it involves the processing of linguistic input. We review studies showing that speakers quickly and implicitly learn restrictions on the syllable positions of consonants as they recite lists of syllables. The learning is revealed in slips of the tongue. For example, if /f/ is artificially restricted to onset position throughout the course of an experiment, when an /f/ is erroneously produced instead of some other consonant, it nearly always occurs in onset position. For this symposium, we present experiments and simulations that use reversal shift to determine the nature of the learning. After implicitly learning, say, that /f/ must be an onset and /s/ must be a coda, the rule is then reversed, e.g. /s/ must be an onset and /f/ must be a coda. When a reversed rule is learned more slowly than the original learning (or a comparable new set of restrictions), this suggests that the original rule must be un-learned before the new rule can be learned, which is classically taken as evidence for purely associative learning. We propose that implicit sequence learning in production is purely associative in just this way.

Toward a Unifying Framework for Implicit Learning and Statistical Learning (Conway)

Despite attempts to unify implicit learning and statistical learning research (e.g., Perruchet & Pacton, 2006), these two areas continue to proceed relatively independently of the other. Perhaps one reason for this compartmentalization is that each research realm traditionally has relied on different types of tasks: the serial-reaction time and artificial grammar learning tasks for implicit learning research and the word segmentation task for statistical learning. In addition, there are currently very few theoretical frameworks that adequately encompass findings from both areas. In this paper, we argue that while implicit learning and statistical learning tasks have important methodological differences, all three tap into a common ability of humans and other organisms to become sensitive to underlying environmental regularities under incidental conditions and to make predictions (either implicitly or explicitly) about what will be experienced next. We then evaluate a number of current theories related to implicit and statistical learning (e.g., Daltrozzo & Conway, 2014; Frost et al., 2015). Based both upon this analysis and recent findings from our research group, we propose an integrative framework that attempts to provide a unifying account of learning while simultaneously recognizing the heterogeneity of the processes and mechanisms involved. Specifically, we propose that implicit-statistical learning relies upon a distributed network of brain areas and cognitive processes that involve both lower-level implicit-perceptual learning mechanisms and higher-level abstraction, integration, and prediction processes. We close by presenting testable predictions of this framework and areas for future research.

References

Conway, C. M., & Christiansen, M. H. (2006). Statistical learning within and between modalities pitting abstract against stimulus-specific representations. *Psychological Science*, *17*(10), 905-912.

Daltrozzo, J., & Conway, C. M. (2014). Neurocognitive mechanisms of statistical-sequential learning: what do event-related potentials tell us? *Frontiers in Human Neuroscience*, *8*, 437.

Frost, R., Armstrong, B. C., Siegelman, N., & Christiansen, M. H. (2015). Domain generality versus modality specificity: the paradox of statistical learning. *Trends in Cognitive Sciences*, *19*(3), 117-125.

Perruchet, P., & Pacton, S. (2006). Implicit learning and statistical learning: One phenomenon, two approaches. *Trends in Cognitive Sciences*, *10*(5), 233-238.

Saffran, J. R., Aslin, R. N., & Newport, E. L. (1996). Statistical learning by 8-month-old infants. *Science*, *274*(5294), 1926-1928.

Reber, A. S. (1967). Implicit learning of artificial grammars. *Journal of Verbal Learning and Verbal Behavior, 6*, 855-863.