

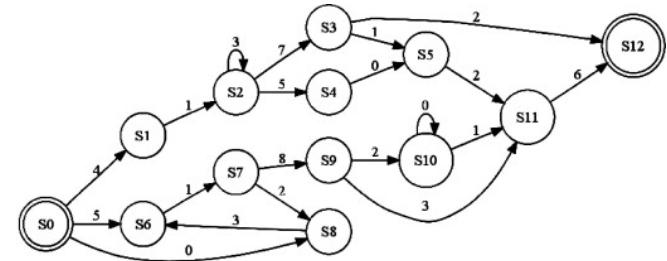
A single paradigm for implicit and statistical learning

August 11, 2016, CogSci 2016

Padraic Monaghan and Patrick Rebuschat

Two approaches, one phenomenon

- Past 20 years witnessed strong, growing interest in **our ability to rapidly extract information from complex stimulus environments.**



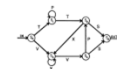
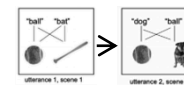
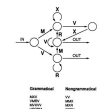
Finite-state grammar

$S_0 \rightarrow 4 S_1$	$S_2 \rightarrow 3 S_2$	$S_4 \rightarrow 0 S_5$	$S_8 \rightarrow 3 S_6$
$S_0 \rightarrow 0 S_8$	$S_2 \rightarrow 7 S_3$	$S_5 \rightarrow 2 S_{11}$	$S_9 \rightarrow 2 S_{10}$
$S_0 \rightarrow 5 S_6$	$S_2 \rightarrow 5 S_4$	$S_6 \rightarrow 1 S_7$	$S_9 \rightarrow 3 S_{11}$
$S_1 \rightarrow 1 S_2$	$S_3 \rightarrow 1 S_5$	$S_7 \rightarrow 2 S_8$	$S_{10} \rightarrow 0 S_{10}$
	$S_3 \rightarrow 2 S_{12}$	$S_7 \rightarrow 8 S_9$	$S_{10} \rightarrow 1 S_{11}$
			$S_{11} \rightarrow 6 S_{12}$
			$S_{12} \rightarrow \epsilon$

Regular expression

$(4 1 3^* (7 2 | (7 1 | 5 0) 2 6) | ((0 3 | 5) 1 (2 3 1)^* 8 (3 | (2 0^* 1) 6)$

Musical terminals



Two approaches, one phenomenon

- Two related, yet completely distinct research strands:



Implicit learning

- Reber (1967, 1969) onwards
- Major strand in cognitive psychology



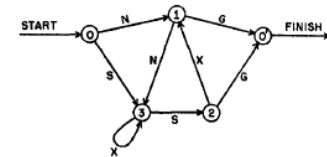
Statistical learning

- Saffran, Aslin, and Newport (1996)
- Major strand in developmental psychology

Commonalities

- Shared origin

- Miller (1958), Aborn & Rubenstein (1952), Horowitz & Jackson (1959), Braine (1963), Bogartz & Caterette (1963), Smith (1963), Segal & Halwes (1965), Foss (1968), etc.



RULES OF TRANSITION:
 (0,N,1) (1,N,3) (2,G,0) (3,S,2)
 (0,S,3) (1,G,0) (2,X,1) (3,X,3)

Class 1	Class 2	Class 3	Class 4
ZAP	YAV	KER	EMP
ZAS	YAD	KEZ	ERT
ZOP	YOM	KIF	INF
ZOT	YOG	KIB	IPS

- Shared methodology

- Use of artificial languages to investigate learning and memory

Form A		Form B		
Exp I	Exp II	Exp I	Exp II	
Size 1	ludnas	vuskof	ludzig	sebvus
Size 2	grdnas	naspof	grdzig	sebvus
Size 3	sebnas	zippof	sebzig	zigseb
Size 4	pofnas	tavpof	pozzig	tavseb

- Shared belief

- Artificial languages, including FSGs, can tell us something how we learn natural language

Form C		Form D		
Exp I	Exp II	Exp I	Exp II	
Size 1	ludtav	vusgrč	ludvus	vustlud
Size 2	grčtav	nasgrč	grčvus	nevlud
Size 3	sebtav	ziggrč	sebvus	ziglud
Size 4	poftav	tavgrč	poftvus	tavlud

FIGURE 2. THE FOUR FORMS USED AS STIMULUS FIGURES.

Commonalities

Review **TRENDS in Cognitive Sciences** Vol.10 No.5 May 2006 www.trends-cogsci.com

Implicit learning and statistical learning: one phenomenon, two approaches

Pierre Perruchet and Sebastian Pasten

Université de Bourgogne, LEAD/CNRS, Pôle AAFE, Esplanade Erasme, 21000 Dijon, France

The domain-general learning mechanisms elicited in incidental learning situations are of potential interest in many research fields, including language acquisition, object knowledge formation and motor learning. They have been the focus of studies on implicit learning for nearly 40 years. Stemming from a different research tradition, studies on statistical learning carried out in the past 10 years after the seminal studies by Saffran and collaborators, appear to be closely related, and the similarity between the two approaches is strengthened further by their recent evolution. However, implicit learning and statistical learning research favor different interpretations, focusing on the formation of chunks and statistical computations, respectively. We examine these differing approaches and suggest that this divergence opens up a major theoretical challenge for future studies.

Introduction

There is no doubt that many of our most fundamental abilities, whether they concern language, perception, motor skill, or social behavior, reflect some kind of adaptation to the regularities of the world that evolves without intention to learn, and without a clear awareness of what we know. This ubiquitous phenomenon was called 'implicit learning' (IL) by Reber (11, 12) 40 years ago. Since then, several studies have explored this form of learning with several experimental paradigms (mainly finite-state grammars and serial reaction time tasks; for reviews, see [3, 4]).

Originating from a different research tradition, the term 'statistical learning' (SL) was proposed 10 years ago by Saffran and collaborators (4) to designate the ability of infants to discover the words embedded in a continuous artificial language, and this field of research is now growing exponentially. There are obvious similarities between SL and IL. As in IL, participants in SL experiments are faced with structured material without being instructed to learn. They learn merely from exposure to positive instances, without engaging in analytical processes or hypothesis-testing strategies. Researchers have pointed out that SL processes

Corresponding author: Perruchet, P. (e-mail: pierre.perruchet@u-bourgogne.fr)

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automatically (5–8), incidentally (9), spontaneously (6), or by simple observation (9), and that participants in SL settings were unaware of the statistical structure of the material (7).

This article first describes how recent evolution in IL and SL research fields has made them closer to one another, leading to a growing number of cross-references and to the occasional use of the two expressions as synonymous. Conway and Christiansen (10) even now propose the term 'implicit/statistical learning' to cover the two domains. However, we then go on to show that beyond the similarity of paradigms and results, the two domains emphasize different interpretations of the data. We suggest that this divergence, which has not been highlighted as yet, opens up a deep challenge for future studies.

The recent evolution of IL and SL studies

Ten years ago, it seemed possible to contrast IL and SL on their main issues of interest, namely syntax acquisition and lexicon formation, respectively. Indeed, the task-learned material used in artificial grammar learning research is typically governed by rules, that is by organizing principles which are independent of the specific material used in a given instance. If participants learned the rules, then this form of learning would be out of the scope of SL studies, in which the notion of rules is a priori irrelevant. However, research from the past few years has made it increasingly clear that participants in artificial grammar learning experiments do not need to extract the rules to perform well, even in situations involving transfer across surface forms (10; 3). In addition, the artificial grammar learning paradigms tend to be now supplanted by other paradigms, such as the serial reaction time tasks, in which a description of the materials in terms of rules appears less appropriate.

Another initial difference between the two domains was that IL research used a large variety of situations involving different sensory modalities and response systems, whereas SL originally focused on the early stage of language acquisition. However, more recently research on SL has progressively broadened its scope of investigation. The syllables used in the first studies have been replaced by tones with the same results (11, 12). A parallel literature has evolved with visual shapes (6–8), or even tactile stimuli (13). Perhaps even more importantly,

Research Article

Statistical Learning Within and Between Modalities

Pitting Abstract Against Stimulus-Specific Representations

Christopher M. Conway¹ and Morten H. Christiansen²

¹Indiana University and ²Cornell University

ABSTRACT—When learners encode sequential patterns and generalize their knowledge to novel instances, are they relying on abstract or stimulus-specific representations? Research on artificial grammar learning (AGL) has shown transfer of learning from one stimulus set to another, and such findings have encouraged the view that statistical learning is mediated by abstract representations that are independent of the sense modality or perceptual features of the stimuli. Using a novel modification of the standard AGL paradigm, we obtained data to the contrary. These experiments pitted abstract processing against stimulus-specific learning. The findings show that statistical learning results in knowledge that is stimulus-specific rather than abstract. They show furthermore that learning can proceed in parallel for multiple input streams along separate perceptual dimensions or sense modalities. We conclude that learning sequential structure and generalizing to novel stimuli inherently involves learning mechanisms that are closely tied to the perceptual characteristics of the input.

A core debate in the psychological sciences concerns the extent to which acquired knowledge consists of modality-dependent versus abstract representation. Traditional information-processing approaches view cognition as emphasizing the operation of amodal symbol systems (Fodor, 1975; Pylyshyn, 1994), whereas more recently, embodiment and similar theories have proposed instead that cognition is grounded in modality-specific sensorimotor mechanisms (Barsalou, Simmons, Barbey, & Wilson, 2003; Glenberg, 1997). This debate has been especially intense in the area of implicit statistical learning of artificial

grammars.¹ In his early work, A.S. Reber (1967, 1969) demonstrated implicit learning in participants who were exposed to letter strings generated from an artificial grammar. The letter strings obeyed the overall rule structure of the grammar, being constrained in terms of which letters could follow which other letters. Participants not only showed evidence of learning this structure implicitly, but also could apparently transfer their knowledge of the legal regularities from one letter vocabulary (e.g., M, R, T, V, X) to another (e.g., N, P, S, W, Z) as long as the same underlying grammar was used for both (A.S. Reber, 1969). This effect has been replicated many times, with transfer being demonstrated not just across letter sets (e.g., Brooks & Vakey, 1991; Mathews et al., 1989; Shanks, Johnston, & Stage, 1997), but also across sense modalities (Altmann, Dienes, & Goode, 1995; Murray & Reber, 1997; Murray & Altmann, 2001).

Transfer effects in artificial grammar learning (AGL) are usually explained by proposing that the learning is based on abstract knowledge, that is, knowledge not directly tied to the surface features or sensory instantiation of the stimuli (Altmann et al., 1995; Pons, Bonatti, Nespor, & Mehler, 2002; A.S. Reber, 1969; Shanks et al., 1997). For instance, the human cognitive system might encode patterns among stimuli in terms of 'abstract algorithm-like rules' that encode relationships among amodal variables (Marcus, Vijayan, Tan, & Vishton, 1999, p. 79). Such a proposal emphasizes the learning of structural information among items and deemphasizes the acquisition of information pertaining to specific features of the stimulus elements. Alternatively, participants may learn the statistical structure of the input sequences using associative mechanisms that are sensitive to modality- or stimulus-specific features (e.g., Chang & Knowlton, 2004; Christiansen & Curtis, 1999; Conway

Address correspondence to Christopher M. Conway, Department of Psychology, 1103 E. 10th St., Indiana University, Bloomington, IN 47405, e-mail: conway@indiana.edu.

¹Artificial grammar learning is restricted in the sense that successful performance can be achieved by encoding surface skills in the frequency of chunks of letters (Perruchet & Pasten, 1993), by learning the transitional probabilities among consecutive elements (Coffman, Johnson, Adin, & Nespor, 1999).

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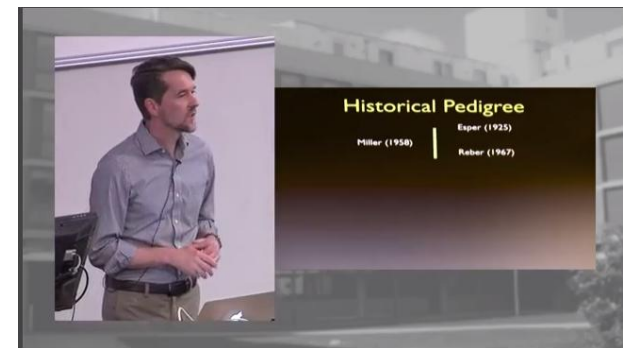
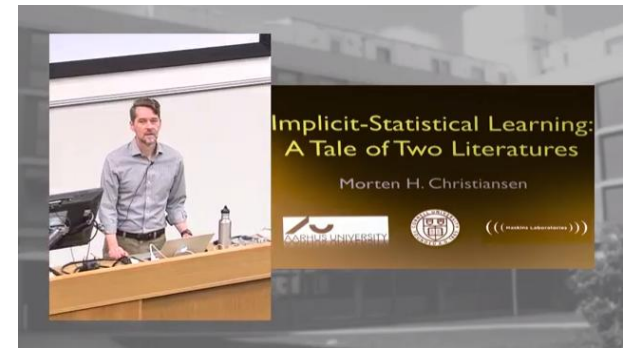
Commonalities

Great introduction to the “Tale of Two literatures” → **Morten Christiansen** keynote at Fifth Implicit Learning Seminar

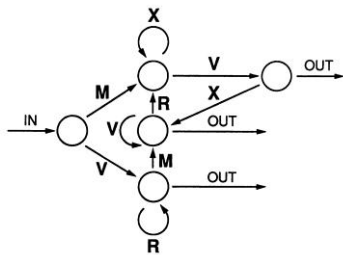
www.lancaster.ac.uk/implicit-learning-seminar

<https://youtu.be/LH85UFsxjqA>

See tweet (@prebuschat) with link **#CogSci2016**



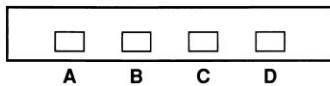
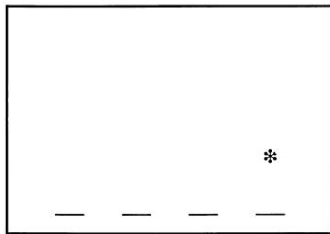
Differences



Grammatical Nongrammatical

MXV VV
 VMRV MMX
 MVXVV MXR
 VRRRM XXXV

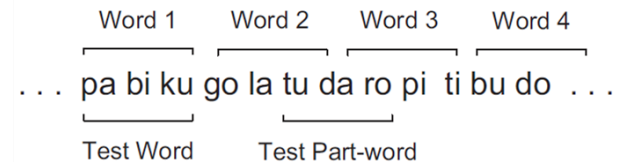
DBCACBDCBA



	Implicit learning	Statistical learning
Grammar	FSG	PSG, non-adj dep
Lexicon	Letters	Pseudowords (shapes)
Main paradigms	AGL, SRT	Word segmentation, non-adj dependency learning, CSL
Primary interest	Learning and memory	Language learning (broadening scope, VSL)
Participants	Adults, other primates	Infants, children, adults, other primates

S → A B (C)
 A → a (d)
 B → C f
 B → e
 C → c(d)

a → {hes or vot}
 c → pel
 d → jix
 e → {rud or sog}
 f → {kav or dup}



Exposure condition and awareness

Implicit learning

- Careful manipulation of exposure condition
 - Incidental exposure as default

- Systematic comparison of exposure conditions
 - Incidental vs intentional
 - Reber (1976), Reber et al. (1980), Berry & Broadbent (1988), Broadbent et al. (1986), Mathews et al. (1989), Jimenez (2001), Dienes et al (1991), Destrebcqz (2004), Van den Bos & Poletiek (2008) and many others

Statistical learning

- Exposure is often intentional (“Learn which words go with which objects...”)

- Exposure conditions not systematically compared
 - See Kachergis et al., 2010, 2014; Hamrick & Rebuschat, 2012; Arciuli et al., 2014; Stevens et al., in press, for recent exceptions

Why incidental exposure?

Exposure condition and awareness

Implicit learning

- Focus on whether the acquired knowledge is conscious or not
 - Verbal reports (retrospective)
 - Subjective measures of awareness
 - Objective measures of awareness

Statistical learning

- Typically, no measures of awareness
 - See Hamrick & Rebuschat, 2011, 2012; Batterink et al., 2015; Franco et al., 2016; special issue of Frontiers

Why could it be important to check whether participants acquire implicit (unconscious) knowledge?

Today's studies

- Introduce a paradigm that brings together the two strands
- Illustrate the advantages of combining insights and methods from the two strands → One approach, one phenomenon?
- Two experiments:
 - Paradigm > Cross-situational learning task (SL)
 - Manipulate exposure context (IL)
 - Add measures of awareness (IL)

Experiment 1



Experiment 1

Paradigm:

- Cross-situational learning (Yu & Smith, 2007)
- We used the CSL task developed by Monaghan and colleagues.
- Monaghan & Mattock (2012, Cognition) and Monaghan et al. (2015, Cognitive Science)

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Integrating constraints for learning word-referent mappings

Padraic Monaghan*, Karen Mattock

Center for Research in Human Development and Learning, Department of Psychology, Lancaster University, Lancaster LA1 4YW, UK

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ABSTRACT

Learning word-referent mappings is complex because the word and its referent tend to co-occur with multiple other words and potential referents, which combined can lead to generalization to a host of contexts on learning. Though how these constraints may interact has not been investigated in detail in the paper on integrating constraints between word-referent mappings and cross-situational learning, we present a novel method of child-directed speech that allows both fast-learning and slow-learning words acquired in the absence of referents. We show that when the referents contained only referring words in a word-learning task context, both referents and non-referring words, learners are facilitated when responding with word-referent mappings. However, when the referents contained a mixture of referring and non-referring words, the learning advantage was reduced. These findings suggest that the learning advantage is also contingent on multiple sources of information.

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1. Introduction

There are numerous sources of information present in the child's environment that potentially contribute to word learning, such as representational constraints (Machin, 1990; social and gestural cues (Chaffin, 1992); Tardif, 2003), cross-situational associations (Yu & Smith, 2007), between-word co-occurrences (Dahlab, 1996; Yu & Ballard, 2002), and observational and motoric cues (Dahlab, 1996; Tomasello & Bruner, 1978). The integration of multiple sources of information to facilitate language learning has been a topic of considerable interest (Chaffin, 1992; White & Morgan, 2008), yet the integration of all across different conditions has not received as much attention (though see notable exceptions by Gopfer, White, Anderson, and Bishop (2011), Ishikawa, Ishikawa, and Carlson (2010), and White & Morgan (2008)).

Each source of information bears the complexity of the learning situation, but also enhances the possibilities for multiple, interacting cues to facilitate learning. The importance of this interacting information becomes clear in word learning. For instance, in the child's environment on hearing a particular word there are likely to be multiple possible referents for the word present in the environment. However, over time, the child is likely to observe a co-occurrence of a particular word and a particular referent in the environment. From multiple learning situations, the child may learn that a particular word refers to a particular referent. However, this learning is contingent on the child's ability to integrate the information from multiple sources of information. For instance, in a word-learning task context, when the referents contained only referring words, in a word-learning task context, both referents and non-referring words, learners are facilitated when responding with word-referent mappings. However, when the referents contained a mixture of referring and non-referring words, the learning advantage was reduced. These findings suggest that the learning advantage is also contingent on multiple sources of information.

* Corresponding author. Tel.: +44 (0)1524 536311; fax: +44 (0)1524 536312.
E-mail address: p.monaghan@lancaster.ac.uk (P. Monaghan).

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Gavagai Is as Gavagai Does: Learning Nouns and Verbs From Cross-Situational Statistics

Padraic Monaghan*, Karen Mattock*, Robert A. I. Davies*, Alastair C. Smith*
*Department of Psychology, Center for Research in Human Development and Learning, Lancaster University
*Max Planck Institute for Psycholinguistics

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Abstract

Learning to map words onto their referents is difficult, because there are multiple possibilities for forming these mappings. Cross-situational learning studies have shown that word-object mappings can be learned across multiple situations, so can verbs when presented in a restricted context. However, these previous studies have presented either nouns or verbs in ambiguous contexts and thus bypass much of the complexity of multiple grammatical categories in speech. We show that noun word learning in adults is robust when objects are moving, and that verbs can also be learned from similar scenes without additional syntactic information. Furthermore, we show that both nouns and verbs can be acquired simultaneously, that receiving category-level as well as individual word-level ambiguity. However, nouns were learned more quickly than verbs, and we discuss this in light of previous studies investigating the noun advantage in word learning.

Keywords: Language acquisition; Cross-situational learning; Noun learning; Verb learning; Symbol grounding

1. Introduction

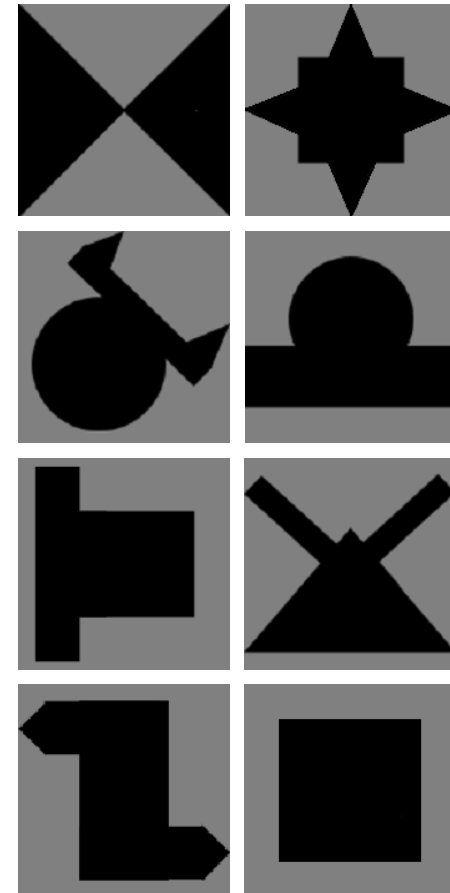
One of the great difficulties for learning words is the potentially infinite number of possibilities for mapping between a word and potential referents, which has become known as the "gavagai" problem (Quine, 1960). Child-directed speech generally comprises utterances containing multiple words, along with multiple potential objects in the child's environment to which any of those words may refer (Yu & Ballard, 2007). Some of the difficulty of resolving the word-referent problem was shown to be at least partially resolved by use of "cross-situational" statistics by the learner (Horton, Scott, & Pollard,

Correspondence should be sent to Padraic Monaghan, Department of Psychology, Lancaster University, Lancaster LA1 4YW, UK. E-mail: p.monaghan@lancaster.ac.uk

Methods: Materials

Cross-situational learning task

- Eight geometric shapes
- Shapes are seen performing one of eight possible motions:
bouncing, growing, hiding, rising, shaking, spinning, swinging



Methods: Materials

Eighteen pseudowords:

- 16 bisyllabic “content” words
 - Eight refer to shapes (“nouns”), eight to motions (“verbs”)
 - Items: barget, bimdah, chelad, dingep, fisslin, goorshell, haagel, jeelow, kerrwool, limeber, makkot, nellby, pakrid, rakken, shooglow, sumbark
- 2 monosyllabic “function” words
 - One precedes shape words (nouns), the other motion words (verbs)
 - Items: tha, noo
- Random assignment to categories

Methods: Materials

- Function words and content words are used to generate sound sequences.
- Four pseudowords in each sequence:
Function word > Content word > Function word > Content word
- Each sequence contains an object-referring phrase (NP) and a motion-referring phrase (VP).
- Phrase sequence is balanced across trials.

Object-referring phrase (Function word > Content word)

Motion-referring phrase (Function word > Content word)

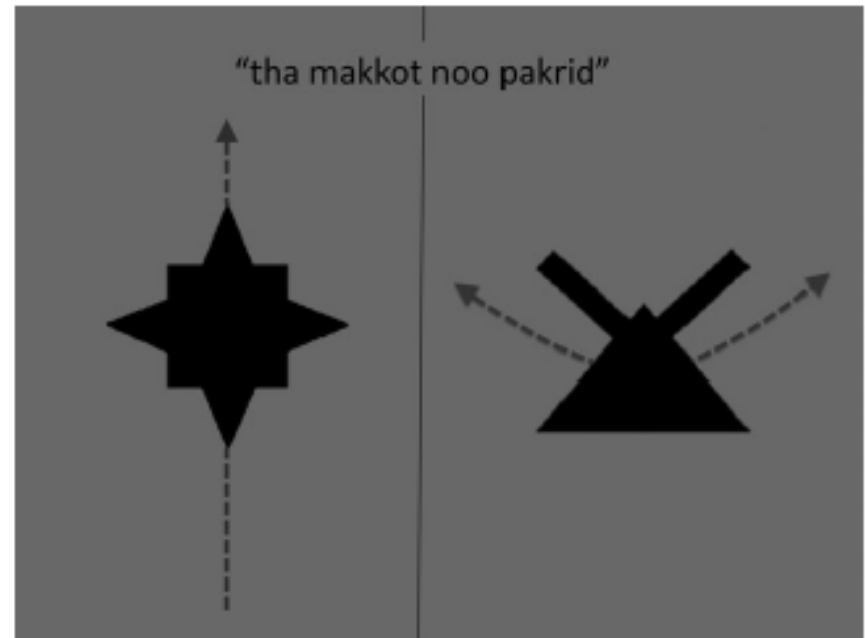
Motion-referring phrase (Function word > Content word)

Object-referring phrase (Function word > Content word)

Methods: Materials

Cross-situational learning task

- Participants observe two scenes.
- Different shapes undergoing different motions.
- After three seconds, sentence played over the headphones
- E.g. “Tha makkot noo pakrid.”
- Participants indicate which of the two scenes the sentence refers to.



No feedback is provided on accuracy of response.



Methods: Participants

- Thirty NS of English, randomly assigned to two exposure conditions: **Incidental vs instructed** (each $n = 15$)
- Participants were told they would see two scenes and hear a sentence. Their task was to choose which scene the sentence refers to (left or right).
- Difference: **Only instructed subjects are told about the function words (tha, noo) and that these always precede shape words (nouns) and motion words (verbs).**

Methods: Procedure

Cross-situational learning task

- Twelve training blocks
 - 24 trials each = 288 exposure trials.
- Testing blocks (13 and 14):
 - Noun test: Two stationary objects, one shape word is played. Subjects indicate which shape it refers to.
 - Verb test: Two scenes, with the same neutral object performing different motions. One motion word is played. Subjects indicate which motion it refers to.

Methods: Procedure

Debriefing questionnaire

- Participants asked if they had noticed any rules or patterns in general.
- Participants then asked if they noticed what type of word always followed the monosyllabic words (*tha* and *noo*).

Verbal reports as measure of awareness

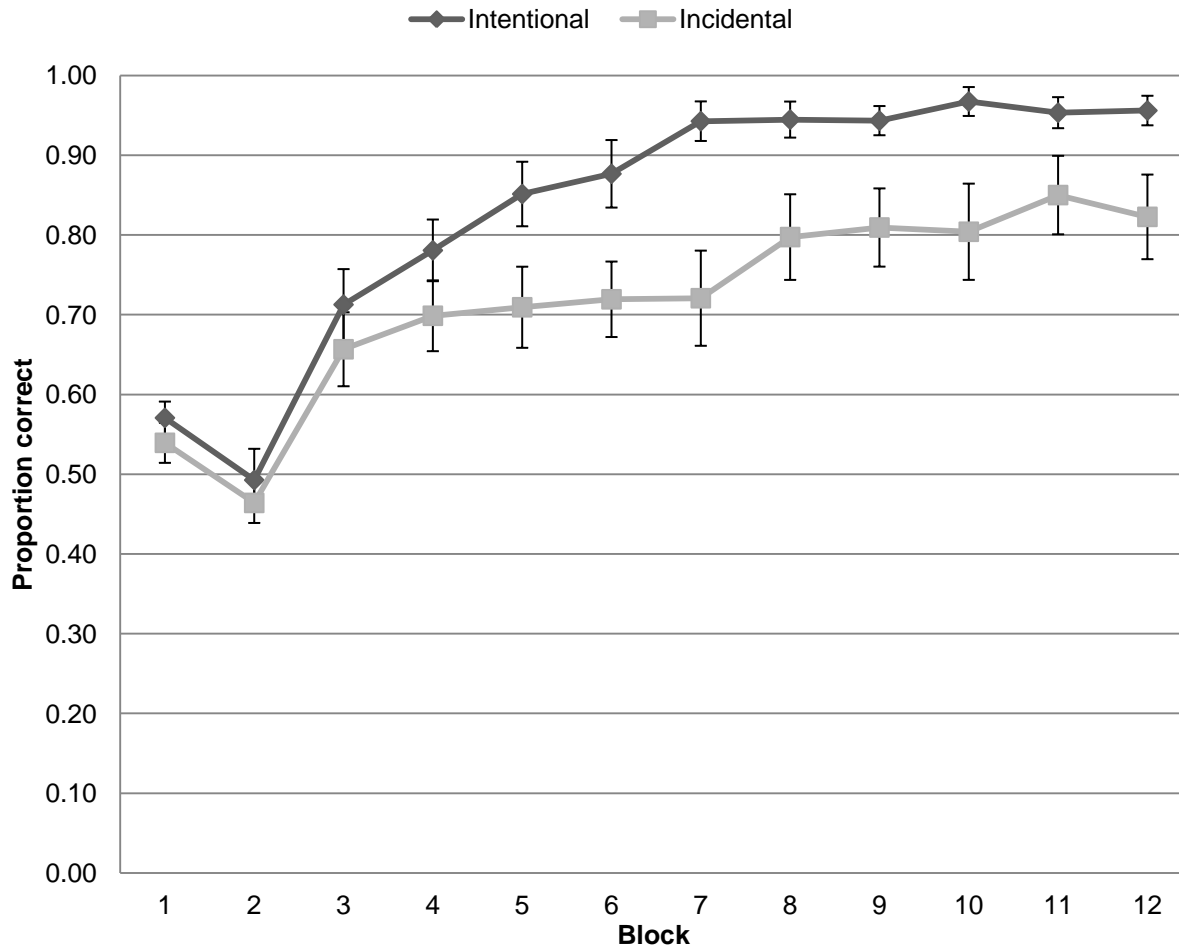
- Lack of verbalization as criterion of implicitness
- Classic measure of awareness (since Reber, 1967)

Results: CSL task

- Overall accuracy across 12 training blocks:
 - Incidental group: 72% *
 - Instructed group: 83%
- Noun test:
 - Incidental group: 83% *
 - Instructed group: 96%
- Verb test:
 - Incidental group: 85% *
 - Instructed group: 96%
- Instructed group sig outperforms incidental group in each case.

Clear learning effect in both groups, with instructed group sig outperforming incidental group in each case.

Results: CSL task



- Incidental group: Sig above chance from block 7
- Instructed group: Sig above chance from block 4
- Significant difference btw groups from block 5.
- Simply telling subjects about function words sig boosts learning.

Results: Verbal reports

Were participants aware of the function words and the role they played?

- Instructed group:
 - Yes, of course. (We had told them.)
- Incidental group:
 - Seven remained unaware of the role of the function words.
 - Seven subjects aware of both function words and of the types of words with which they were associated.
 - This explicit (conscious) knowledge was acquired as a result of exposure.

Results: Aware vs unaware subjects

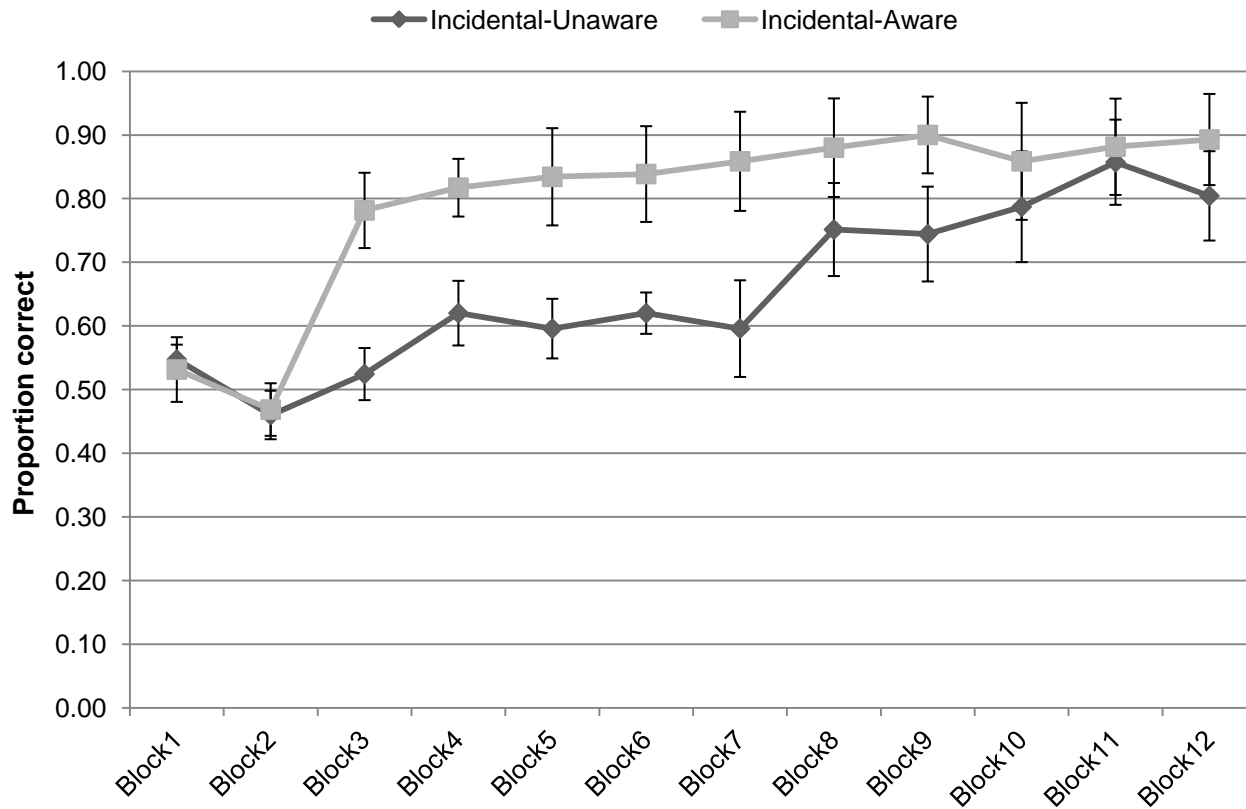
These are subjects from the incidental group.

- Overall accuracy across 12 training blocks:
 - Unaware subjects: 66%
 - Aware subjects: 80%
- Noun test:
 - Unaware subjects: 79%
 - Aware subjects: 89%
- Verb test:
 - Unaware subjects: 84%
 - Aware subjects: 87%

Clear learning effect in both subgroups, but no significant differences between groups.

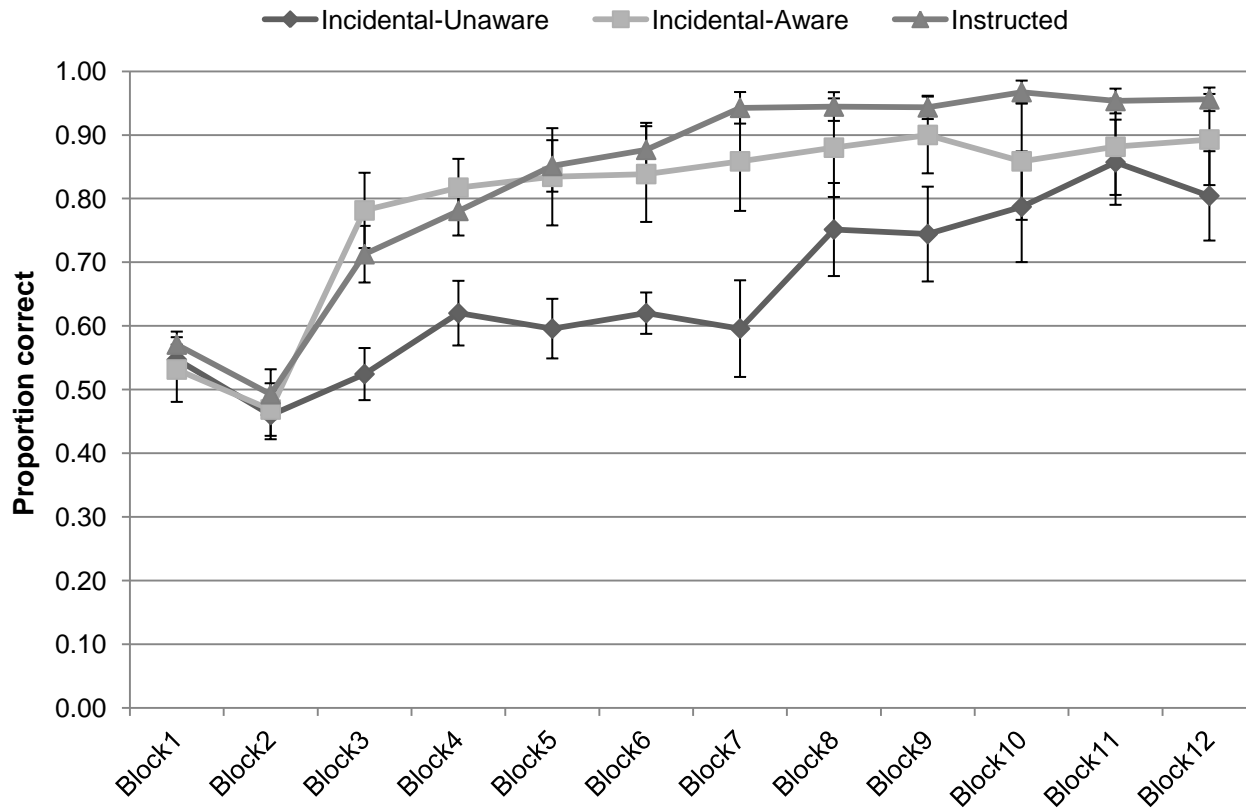
But...

Results: Aware vs unaware subjects



- Unaware subgroup: Sig above chance from block 8
- Aware subgroup: Sig above chance from block 5
- Significant difference btw subgroups btw blocks 3 and 7.
- Exposure > testing paradigms cannot capture the difference!

Results: Aware vs unaware subjects



- Unaware subgroup: Sig above chance from block 8
- Aware subgroup: Sig above chance from block 5
- Significant difference btw subgroups btw blocks 3 and 7.
- Subjects with explicit knowledge perform better.

Experiment 1: Summary

- Adult subjects can rapidly learn novel nouns and verbs without intending to, without feedback, and without becoming aware of the knowledge they have acquired.
- Does explicit knowledge make a difference? Yes!
 - Simply telling subjects about the existence of function words significantly boosts (statistical) learning.
 - Incidental subjects who figured out the underlying “rule” outperform subjects who did not.

Experiment 1: Summary

- Implicit-explicit interface
 - Impact of explicit knowledge on the implicit-statistical learning mechanism (cf instructed group)
 - How does explicit knowledge emerge as a result of implicit-statistical learning? (cf incidental-aware subgroup)
- Methodological implications: Highlights benefits of comparing of exposure conditions and of adding of awareness measures

Experiment 2



Experiment 2

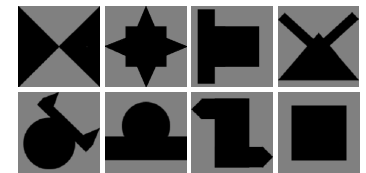
- Adding measures of awareness to expt design is useful.
- Retrospective verbal reports are easy to administer, but there are many limitations:
 - Low confidence knowledge might not be reported
 - Fabrication
 - Unwillingness to report
- Dienes (2004; Dienes & Scott, 2005) and others advocate use of confidence ratings and source attributions as more sensitive measures of awareness

Methods: Materials

Participants: Nineteen NS of English

Same materials as in Expt 1.

- Eight geometric shapes
- Eighteen pseudowords (content + function words)



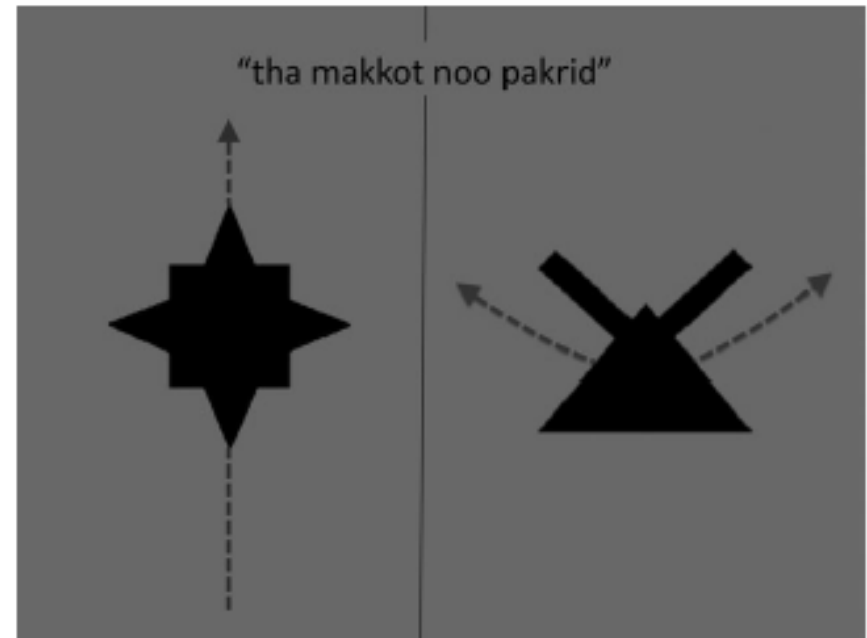
Difference btw Expts 1 and 2:

- Only one condition: incidental
- Two measures of awareness: Verbal reports and subjective measures of awareness

Methods: New procedure

Cross-situational learning task

- Participants observe two scenes.
- After three seconds, sentence played over the headphones.
- Participants indicate which of the two scenes the sentence refers to.
- For each trial, they also report the basis of their decision:
 - Guess
 - Intuition
 } Implicit knowledge
 - Recollection
 - Rule knowledge
 } Explicit knowledge



Subjective measures of awareness
(Dienes, 2004; Dienes & Scott, 2005)

For reviews, see e.g. Rebuschat (2013) and Timmermans (2015).

Experiment 2: Results CSL task

- Overall accuracy across 12 training blocks:
 - Expt 2 – Incidental group: 79%
 - Expt 1 – Incidental group: 72%
- Noun test:
 - Expt 2 – Incidental group: 87%
 - Expt 1 – Incidental group: 83%
- Verb test:
 - Expt 2 – Incidental group: 85%
 - Expt 1 – Incidental group: 85%

Clear learning effect in Expt 2.

Experiment 2: Verbal reports

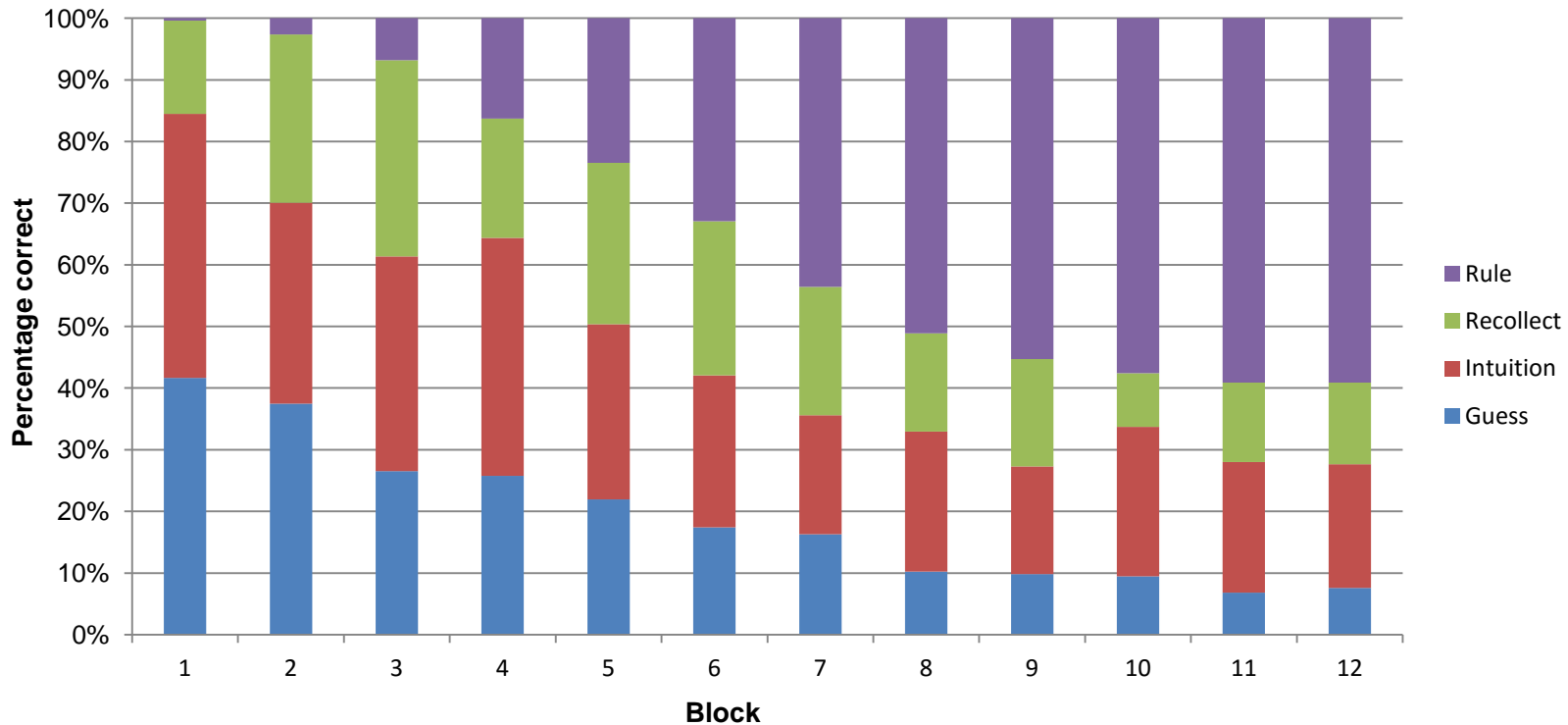
- 17 subjects aware of the function words and of the types of words with which they were associated.
- Only 2 unaware subjects!
- Verbal reports in Expt 2 suggest exposure resulted primarily in conscious (explicit) knowledge. Minimal evidence for unconscious (implicit) knowledge.

For comparison:

- Expt 1 – 50% aware subjects
- Expt 2 – 90% aware subjects

Experiment 2: Subjective measures

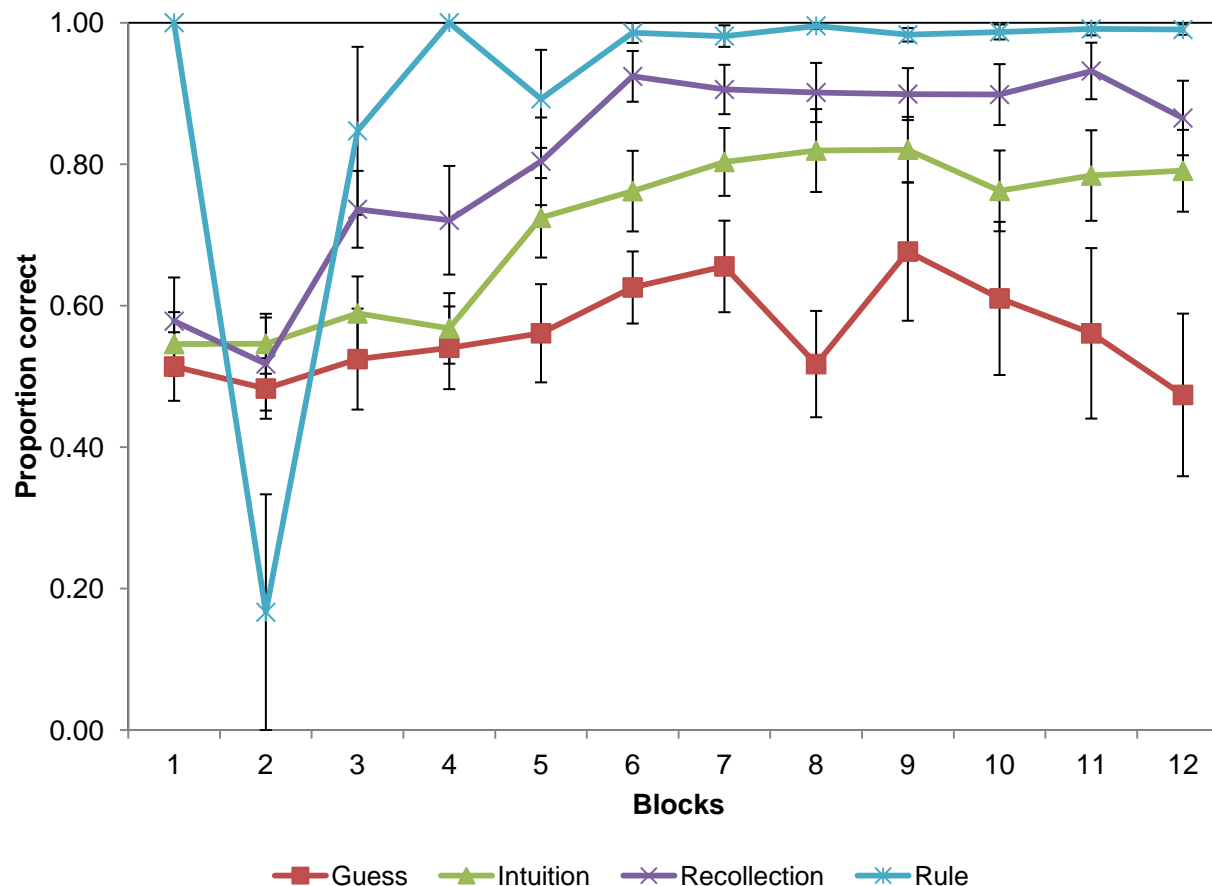
Proportions of decisions attributed to the four source categories (across the 12 blocks of the CSL task)



- Shift from reliance on implicit knowledge categories to explicit knowledge categories.

Experiment 2: Subjective measures

Accuracy across the 12 blocks of the CSL task based on source attribution categories



Decisions based on...

- guesses above chance on blocks 6, 7, 9
- intuition above chance from block 5 onwards
- recollection above chance from block 3 onwards
- rule knowledge above chance on block 3 and then from block 5 onwards
- **Subjects developed both implicit and explicit knowledge**
- **Cf verbal reports**

Discussion

- Expt 2 demonstrates the usefulness of adding more than one measure of awareness.
 - Verbal reports do not provide complete picture.
 - Source attributions show the picture is more interesting, complex.
- Expt 2 also shows that adding subjective measures could potentially influence performance during learning
 - Increase in number of aware subjects
 - Possible improvement in learning?
- Important trend: Systematic comparison of awareness measures (Rebuschat et al., 2015; Franco et al., 2016, etc.)

Summary

- Advantage of experimental tasks that allow tracking of learning during exposure phase (see also SRT...)
- Advantage of carefully controlling exposure condition (and then checking what impact this has on the learning process and the learning product)
- Advantage of adding measures of awareness

A single paradigm for implicit and statistical learning

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Padraic Monaghan and Patrick Rebuschat