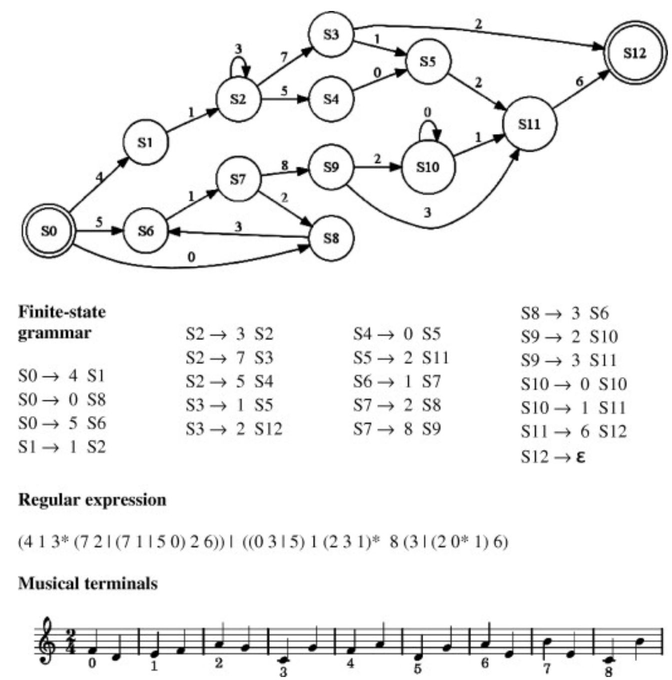
A single paradigm for implicit and statistical learning

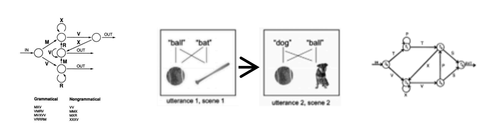
August 11, 2016, CogSci 2016

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**.





Two approaches, one phenomenon

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- Two related, yet completely distinct research strands:

Implicit learning

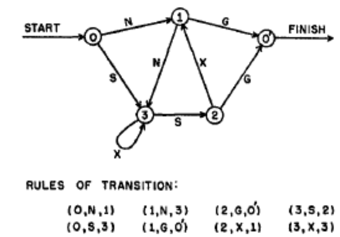
- Reber (1967, 1969) onwards
- Major strand in cognitive psychology

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.
- Shared methodology
  - Use of artificial languages to investigate learning and memory
- Shared belief
  - Artificial languages, including FSGs, can tell us something how we learn natural language



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

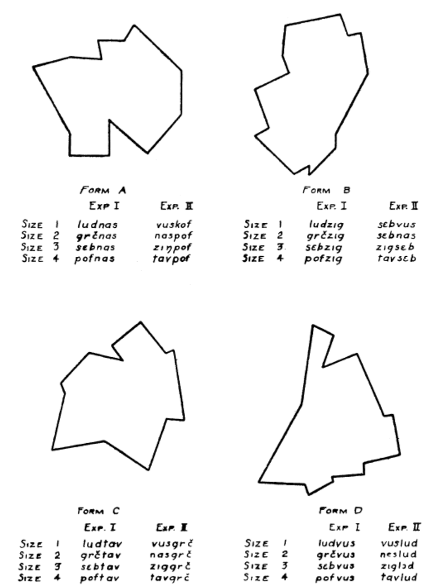
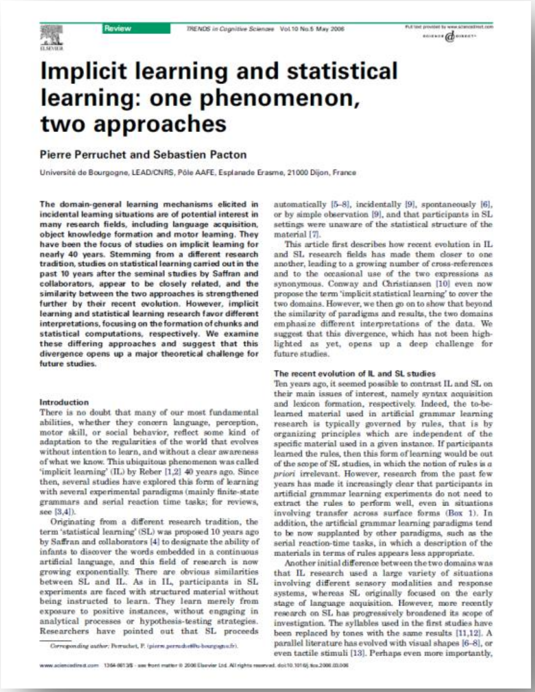


Figure 2. The four forms used as stimulus figures.

Commonalities

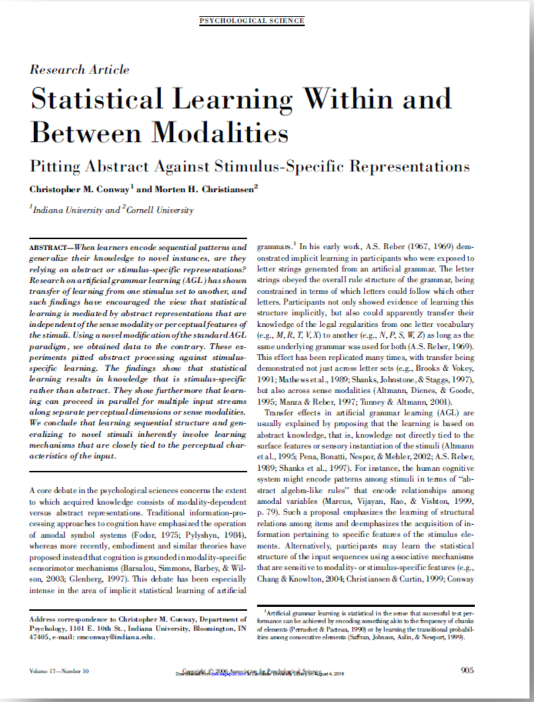

Review TRENDS in Cognitive Sciences Vol.10 No.5 May 2006

Implicit learning and statistical learning: one phenomenon, two approaches

Pierre Perruchet and Sebastien Pacton

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.


PSYCHOLOGICAL SCIENCE

Research Article

Statistical Learning Within and Between Modalities

Pitting Abstract Against Stimulus-Specific Representations

Christopher M. Conway[1] and Morten H. Christiansen[2]

[1]*Indiana University and* [2]*Cornell 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 involve learning mechanisms that are closely tied to the perceptual characteristics of the input.*

Commonalities

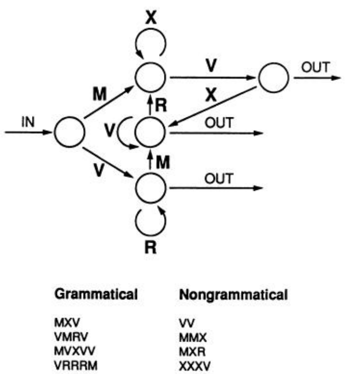
Great introduction to the "Tale of Two literatures" → **Morten Christiansen** keynote at Fifth Implicit Learning Seminar

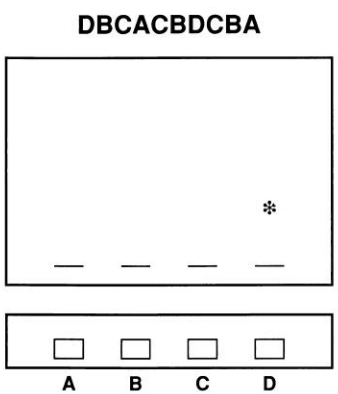
www.lancaster.ac.uk/implicit-learning-seminar

https://youtu.be/LH85UFsxjqA

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

Differences

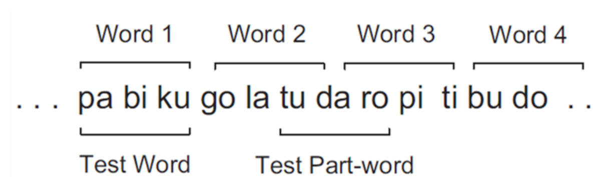




	Implicit learning	Statistical learning
Grammar	FSG	PSG, non-adj dep
Lexicon	Letters	Pseudowords (shapes)
Main paradigms	AGL, SRT	Word segmentation, non-adj dependency learning, CSL
Primary interest	Learning and memory	Language learning (broadening scope, VSL)
Participants	Adults, other primates	Infants,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

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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

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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

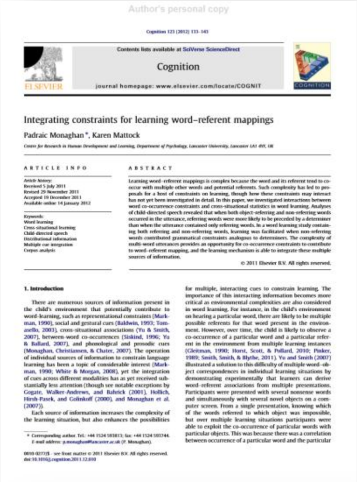
- Introduce a paradigm that brings together the two strands
- Illustrate the advantages of combining insights and methods from the two strands → One approach, one phenomenon?
- Two experiments:
  - Paradigm > Cross-situational learning task (SL)
  - Manipulate exposure context (IL)
  - Add measures of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

Experiment 1

Experiment 1

Paradigm:

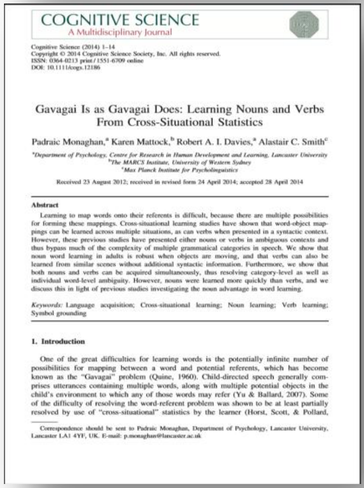
- Cross-situational learning (Yu & Smith, 2007)
- We used the CSL task developed by Monaghan and colleagues.
  - Monaghan & Mattock (2012, Cognition) and Monaghan et al. (2015, Cognitive Science)



Cognition

Integrating constraints for learning word–referent mappings

Padraic Monaghan *, Karen Mattock



COGNITIVE SCIENCE

A Multidisciplinary Journal

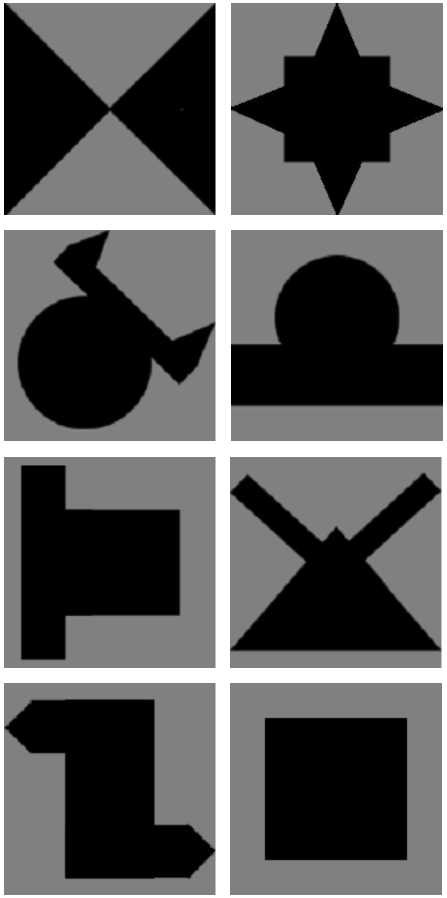
Gavagai Is as Gavagai Does: Learning Nouns and Verbs From Cross-Situational Statistics

Padraic Monaghan,[a] Karen Mattock,[b] Robert A. I. Davies,[a] Alastair C. Smith[c]

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, haagle, jeelow, kerrwoll, 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

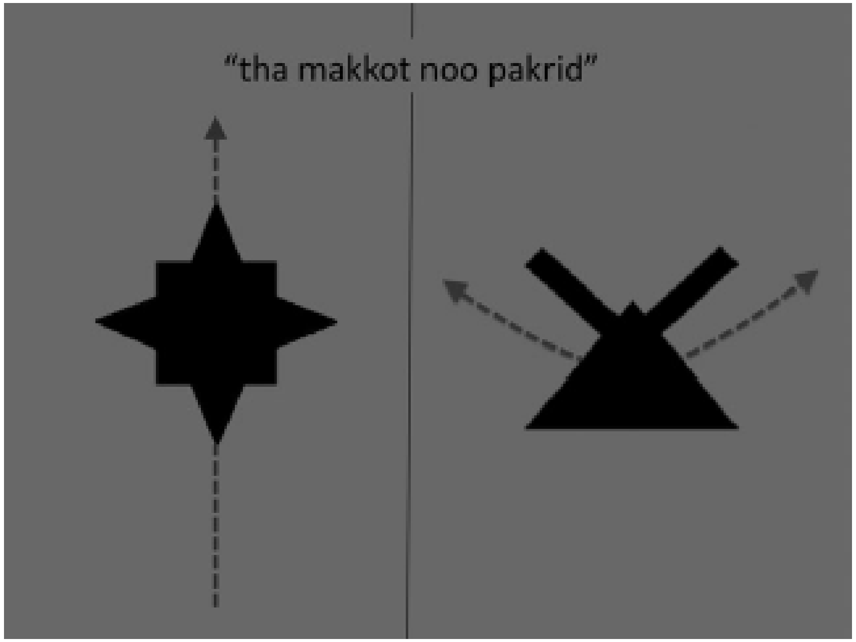
- Function words and content words are used to generate sound sequences.
- Four pseudowords in each sequence:
  Function word > Content word > Function word > Content word
- Each sequence contains an object-referring phrase (NP) and a motion-referring phrase (VP).
- Phrase sequence is balanced across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



<u>No feedback is provided on accuracy of response.</u>

Methods: Participants

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- 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

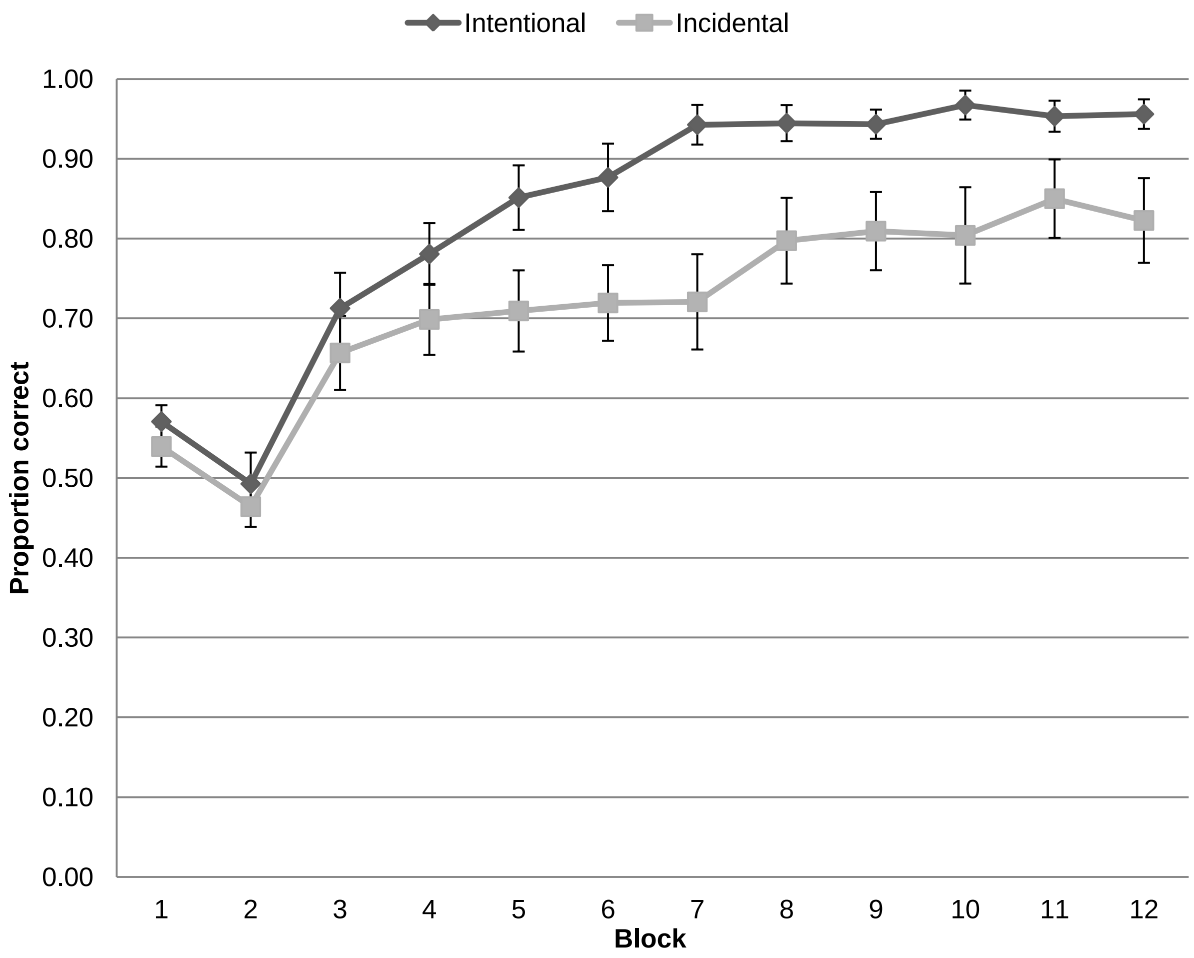
- Lack of verbalization as criterion of implicitness
- Classic measure of awareness (since Reber, 1967)

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.
- <u>Simply telling subjects about function words sig boosts learning.</u>

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 <u>unaware</u> of the role of the function words.
  - Seven subjects <u>aware</u> 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

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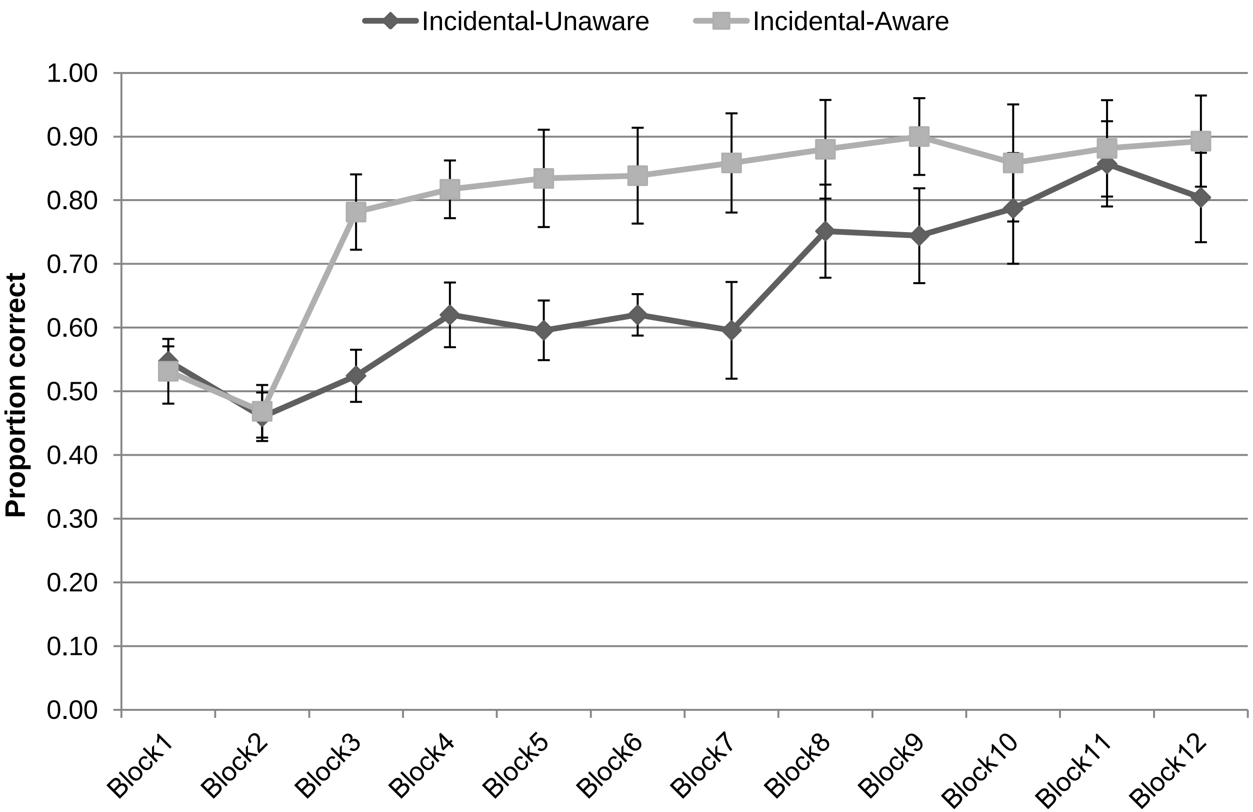
These are subjects from the incidental group.

- 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

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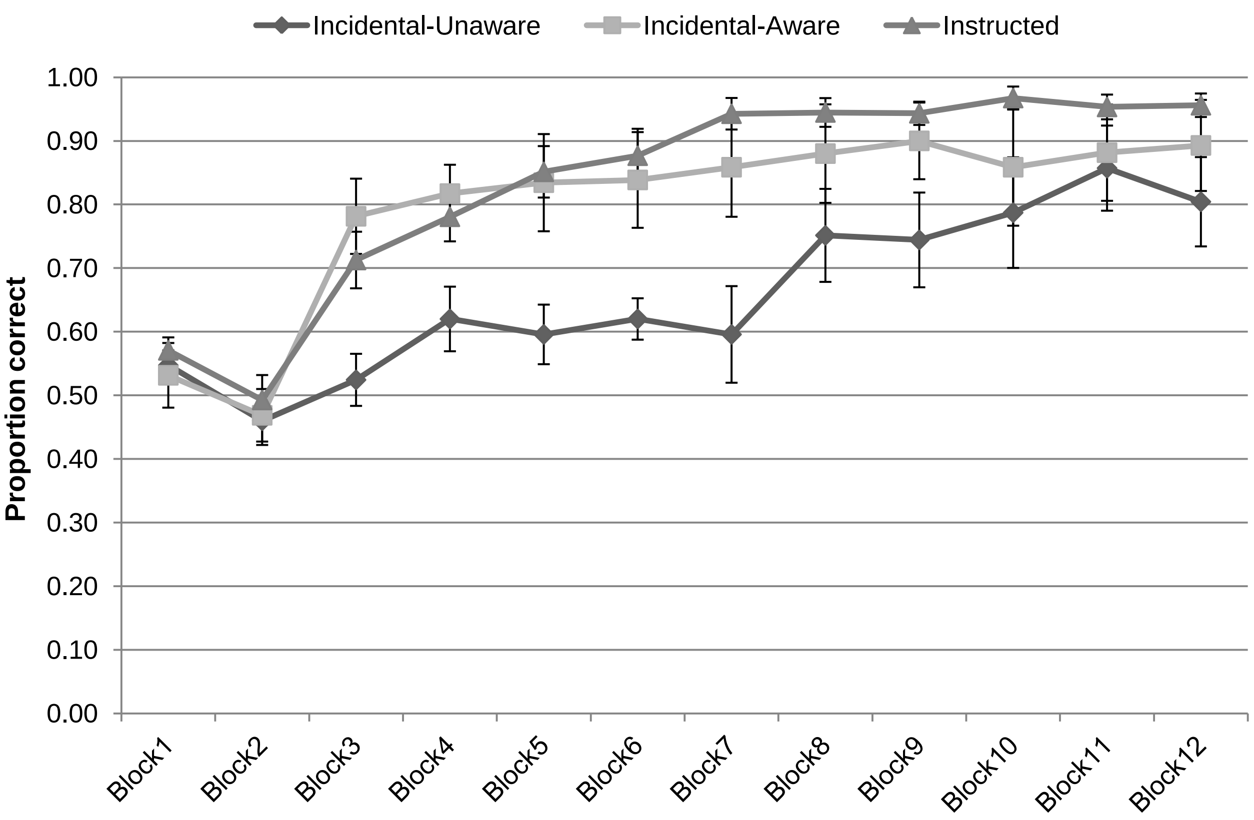

- Unaware subgroup: Sig above chance from block 8
- Aware subgroup: Sig above chance from block 5
- Significant difference btw subgroups btw blocks 3 and 7.
- <u>Subjects with explicit knowledge perform better.</u>

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

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- Adding measures of awareness to expt design is useful.

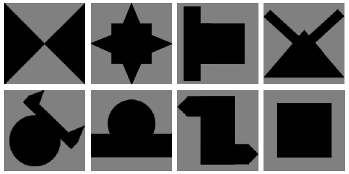
- Retrospective verbal reports are easy to administer, but there are many limitations:
  - Low confidence knowledge might not be reported
  - Fabrication
  - Unwillingness to report

- 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

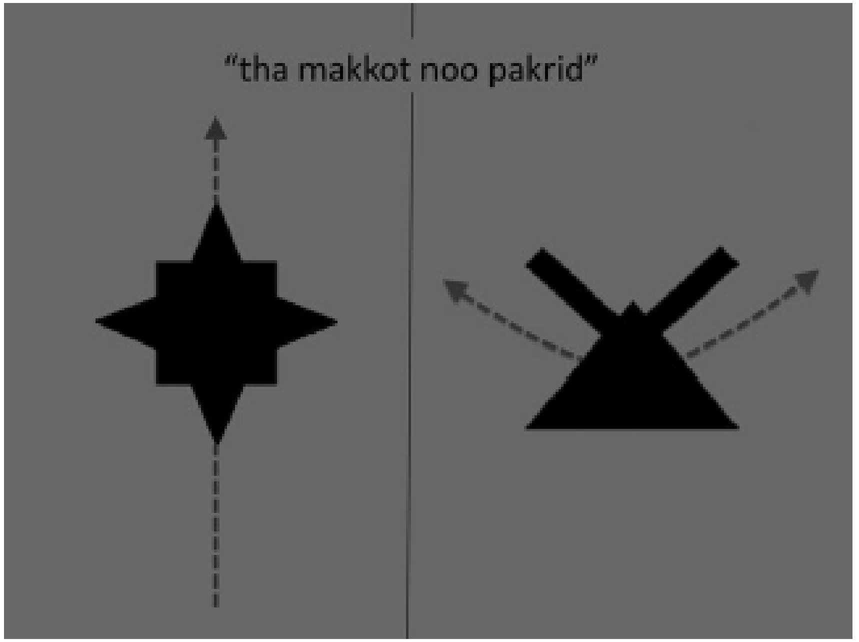
Methods: New procedure

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
  - Recollection
  - Rule knowledge

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

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- 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

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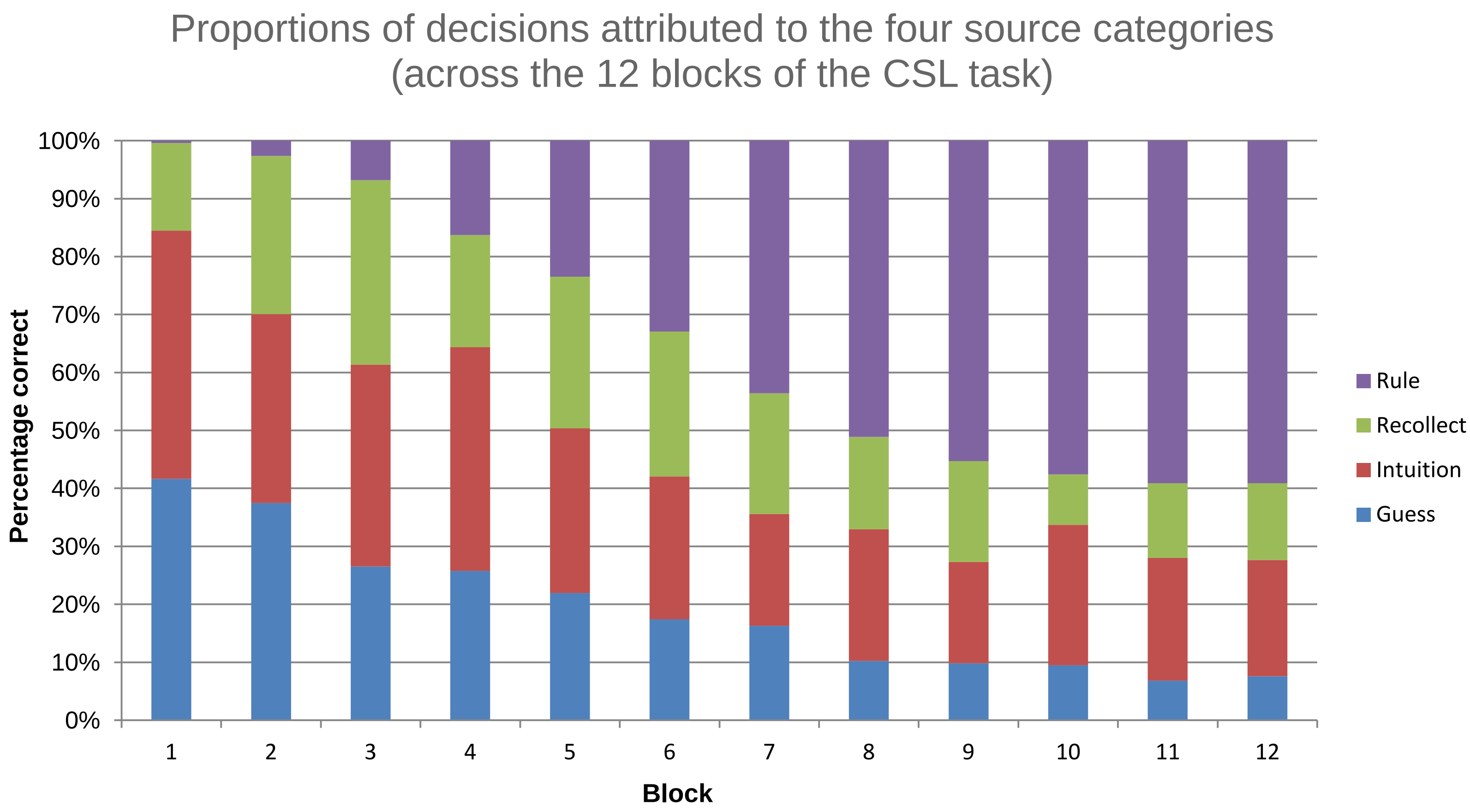

- Shift from reliance on implicit knowledge categories to explicit knowledge categories.

Experiment 2: Subjective measures

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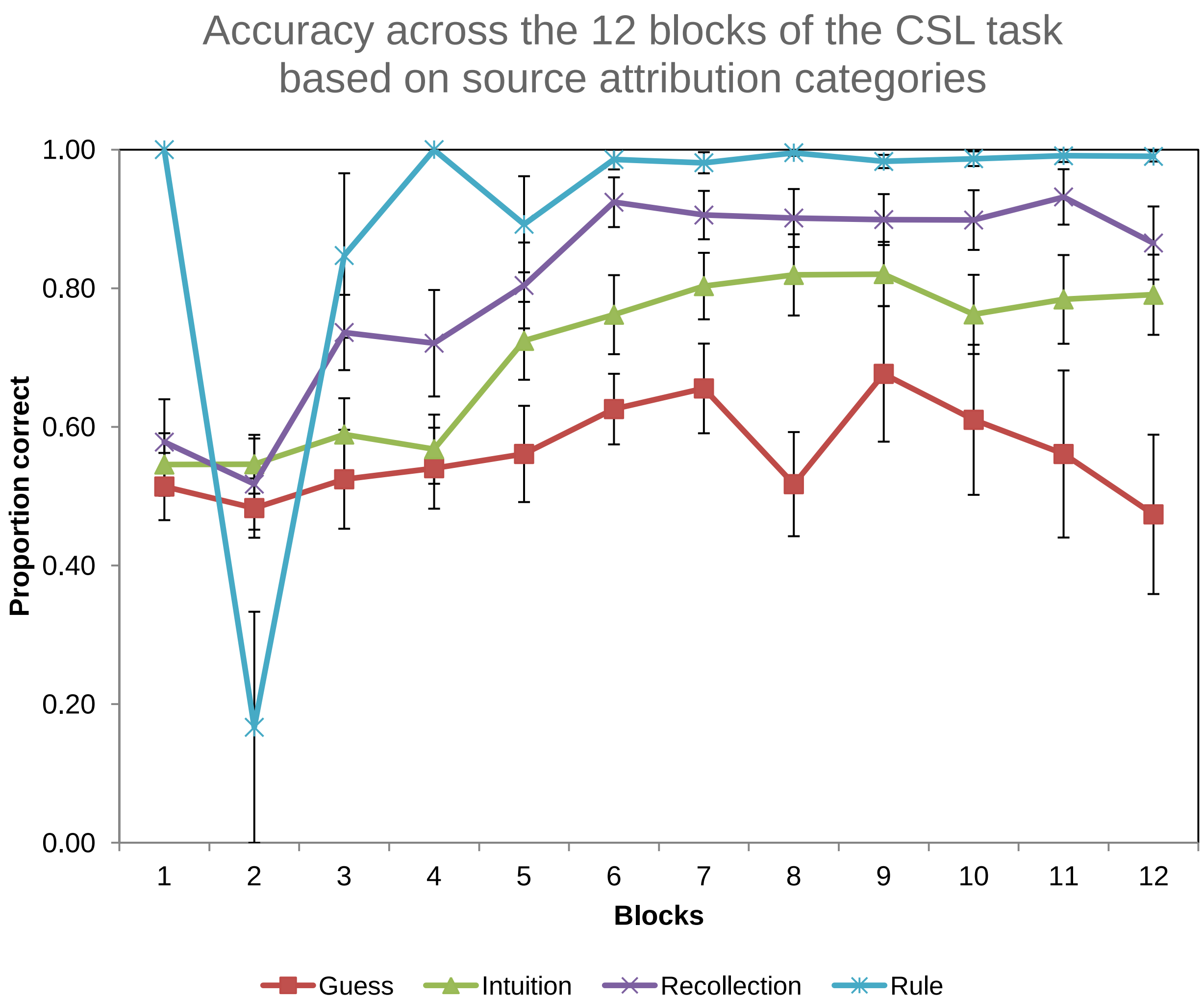

Decisions based on…

- 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

August 11, 2016, CogSci 2016

Padraic Monaghan and Patrick Rebuschat