Social Impact and Cognitive Simplicity and in Semantic Alignment

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Language

- culturally shared set of conventional mappings between symbols and meanings
- language is shaped while being repeatedly transmitted, learned and used in interaction
- many properties of language stem from co-occurring extra-linguistic constraints [Christiansen and Chater, 2016a]:
  - cognition (e.g., pressure for efficiency)
  - society (e.g., imitation highly ranked individuals)
  - ecological conditions (e.g., pressure for expressiveness)

Meaning as Algorithm

[Tichy, 1969, Suppes, 1980]:

meaning = procedure (algorithm)

The basic and fundamental psychological point is that, with rare exceptions, in applying a predicate to an object or judging that a relation holds between two or more objects, we do not consider properties or relations as sets. We do not even consider them as somehow simply intensional properties, but we have procedures that compute their values for the object in question. Thus, if someone tells me that an object in the distance is a cow, I have a perceptual and conceptual procedure for making computations on the input data that reach my peripheral sensory system.

Complexity Measures and Language

- levels of representation [Marr, 1982]
  - computational (input-output function)
  - algorithmic (program computing input-output function)
  - implementation (actual realization, e.g. in the brain)
- complexity measures reflected in cognitive processing:
  - Kołmogorov complexity
    [Feldman, 2000, Chater and Vitányi, 2003]
  - computational complexity [van Rooij, 2008, Szymanik, 2016]
- universal constraint providing selectional pressure for
  - language learning and use [Christiansen and Chater, 2008]
  - language evolution [Kirby et al., 2015]

Social Pressures

- language learning vulnerable to social factors
- imitation involves prestige [Labov, 1972]

> *If a new usage has prestige, i.e., is used by a speaker whom other speakers would like to be associated with (...), then the innovation is likely to catch on and spread*

- effect of prestige found at the phonetic level [Gregory Jr and Webster, 1996]
- selective grammatical alignment [Lev-Ari, 2016]
  - individuals do not learn equally form all speakers
  - more likely to imitate grammatical patterns of people we like

Aim of the study

Focus

Semantic alignment in interaction

Goal

How **semantic complexity**, **social impact** and **contextual complexity** co-influence semantic alignment?

Methodology – experimental semiotics

Experimentation with human subjects engaged in communication games in the lab [Galantucci and Garrod, 2011].

Starting Point

- simple model of semantic alignment [Kalociński et al., 2015]
- space of meanings/procedures/hypotheses
- each procedure classifies stimuli to *examples* and *non-examples*
- procedures (partially) ordered wrt *simplicity*
- each agent has her current hypothesis (procedure)
- n stimuli are presented as a common context
- small n – poor context, big n – rich context
- each agent labels stimuli according to her current hypothesis
- agents observe how others have labelled stimuli
- new current hypothesis = the simplest procedure guaranteeing maximal agreement with the observed labellings (weighted by social impact)

Hypotheses (intuitive formulation)

1. Equal social rank among individuals makes coordination longer (and even longer when contexts are rich)
2. Unequal social rank allows for the emergence of more complex meanings in rich contexts
3. Unequal social rank blocks the emergence of complex meanings when contexts are poor resulting in the lack of convergence or simplifies initial complex meanings.
4. Equal social ranks allow mainly for the emergence of simple meanings (initial complex meanings are largely avoided in the long run)

Attempt of Operationalization

1. signals: ACCEPT/REJECT (YES/NO)
2. meaning = category = concept composed of more basic ones through boolean operations *not*, *or*, *and*, ...

Stimuli & categories

3 dimensions: size (3) x color (3) x shape (3)
$2^{27} \approx 134$ mln categories (mathematically)

size : small, medium, large

color : yellow, blue, black

shape : circle, square, triangle

Stimuli

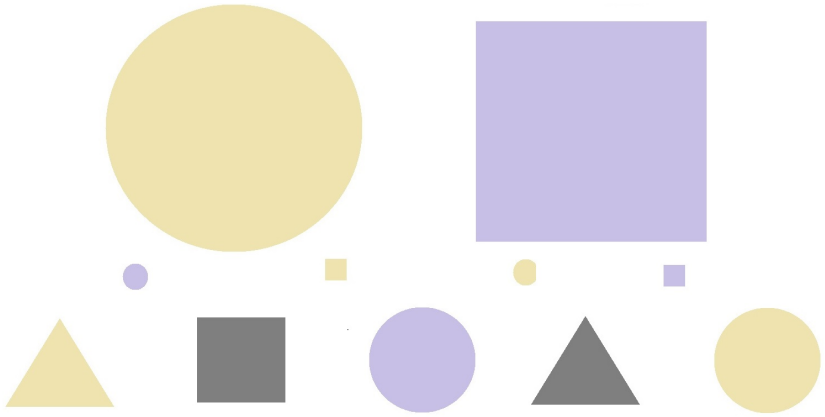


Figure: 11 out of 27 stimuli

Examples of Categories

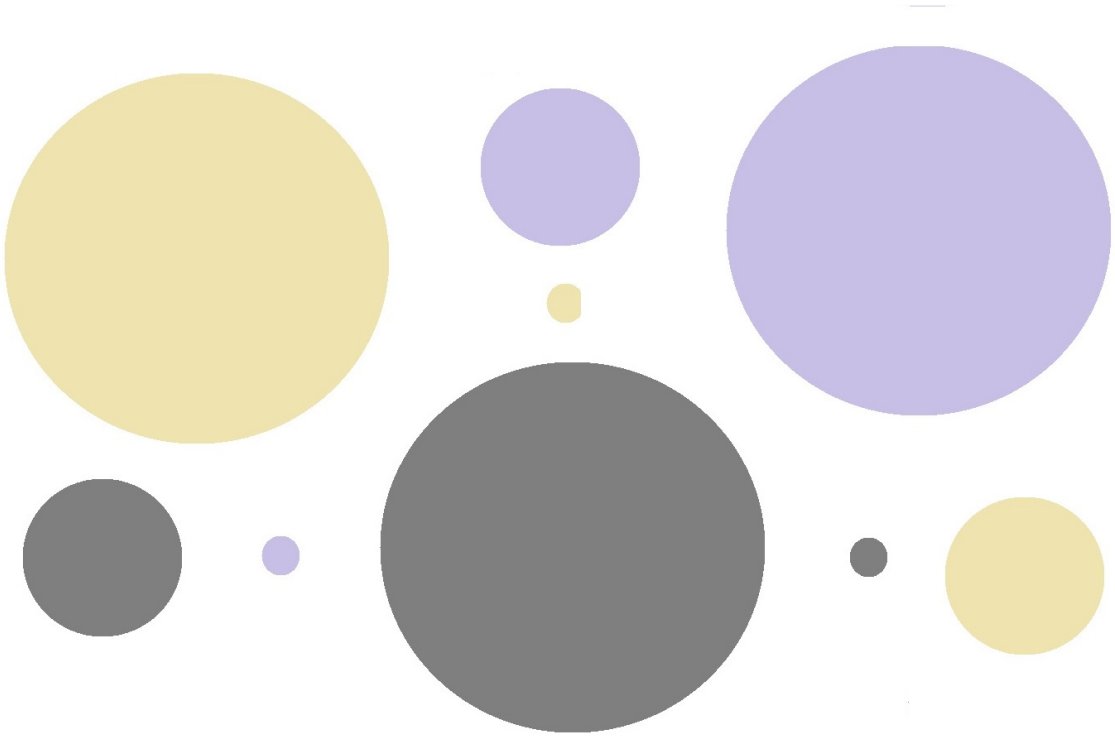


Figure: circle

Examples of Categories

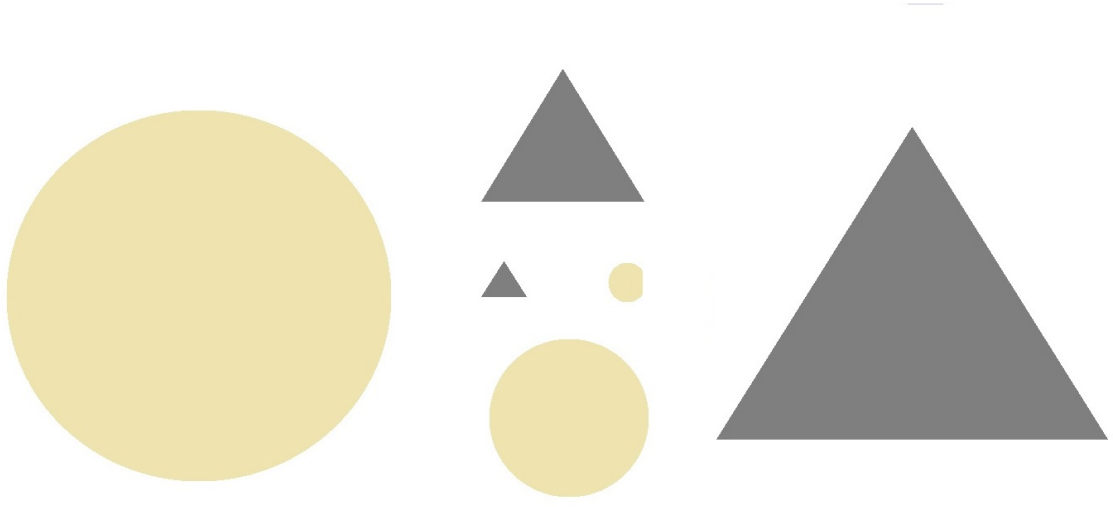


Figure: (circle AND yellow) OR (triangle AND black)

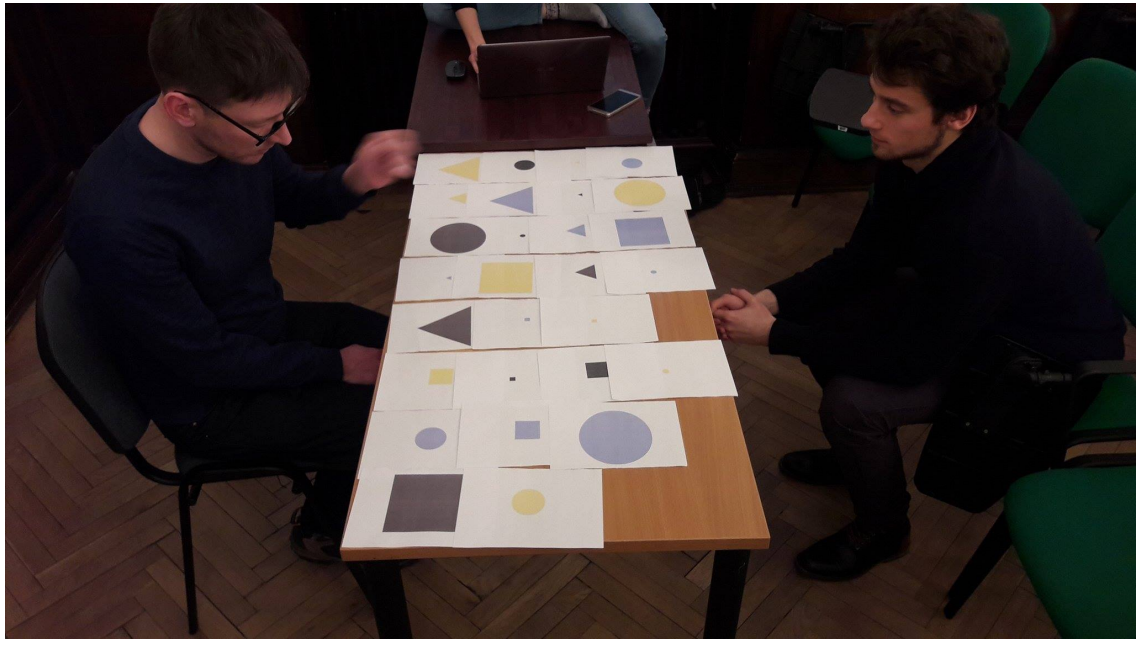
Measure of Simplicity

- Shephard trend [Shepard et al., 1961]
- simplicity of category $\approx$ minimal description length?
- MDL predicts learning difficulty [Feldman, 2000]
- automata-theoretic measure of simplicity? [Szymanik and Zajenkowski, 2010]

Controlling Social Status

- we want ranks to be fixed throughout interaction
- instruct participants about their role in the game
  – "You are the wizard of the village"
- familiar approach in experimental semiotics
- e.g., imposing social rivalry [Roberts, 2008]
- pretesting session – not quite like that:
  - one participant instructed not to change his rule throughout the game ($\approx$ wizard)
  - more like individual supervised learning

Game Designs (incipient)



Overall Picture

- dyads of adults with imposed social roles
- participants are assigned (secretly from one another) initial rules/categories
  - can control semantic complexity!
- participants are told they can change their rules if they want
- they are said the overall goal is to eventually accept/reject the same stimuli (final rule/category)
- participants are not allowed to use natural language, possibly except signalling ACCEPTANCE or REJECTION of occurring stimuli (according to their current rules)
- participants are not allowed to take any notes

Interactional Framework

How much freedom for participants?

Strict, artificial protocol of turn-taking vs more liberal, spontaneous interaction? [Macuch Silva and Roberts, 2016]

Protocol used in mathematical modelling [Kalociński et al., 2015]

Round of interaction:

1. stimulus/i drawn randomly (common context)
2. each agent says which of the stimuli he accepts/rejects according to her present rule (simultaneous exchange)
3. agents can change their rules

Go to next round.

Choices to Make

Stimuli: random/non-random/mixed

1. occurrence of stimuli is driven by external random variable
2. participants are allowed to choose stimuli for interaction (possibly with some restrictions)
   - potential to bootstrap communication

Round in pretests (strict protocol, non-random stimuli):

- sender requests a stimulus of a particular kind (ACCEPTED/REJECTED)
- receiver is allowed to point to one stimulus which he ACCEPTS/REJECTS, accordingly
- roles exchanged, next round

Controlling Contextual Complexity

- context: stimuli directly available in the current interaction
- contextual complexity: number of stimuli directly available to (simultaneously visible by) participants

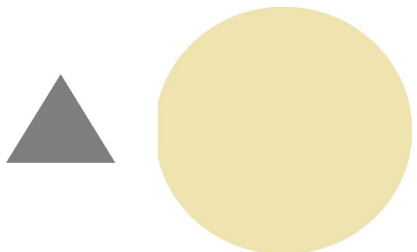
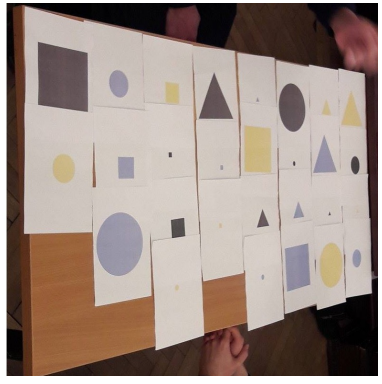


Figure: 2 stimuli per context

Initial Observations

- memory constraints! (pilot study: "Can I make notes?")
- now-or-never bottleneck [Christiansen and Chater, 2016b]
- stimuli arranged on the table
- ⚠external structure for memorization and computation (bad!)
- post-interview: "I accepted all figures to my left." → very complex rule!



Game 1

- Initial rules: P1 circle, P2 blue
- P1 instructed not to change his rule (P2 unaware of that...)
- 41 interactions (15 min)
- lack of convergence
- although in post-interview with P2: "I changed to medium then to small in order to adjust myself. It seemed to me that the rule is *circle*".

Game 2

- Initial rules: P1 triangle, P2 small AND square
- both allowed to change rules at any time
- 15 interactions (10 min)
- convergence: small AND square

Afterthoughts

1. small number of positives affects simplicity (known effect)
2. sort of dialog (last interactions): prompting for ACCEPTED and pointing regularly to all positives

Game 3

- Initial rules: P1 square, P2 blue OR black
- both allowed to change rules at any time
- 36 interactions (15 min)
- convergence: blue AND circle

Afterthoughts

1. similar sort of dialog (last interactions)

Final Concerns and Ideas

- how to control social status/impact and maintain it at a fixed level during the game?
- participants can entertain any rule → pure alignment
- ecological validity (factual constraints)
- signalling games: fixed relation between stimuli and actions
- sender sees stimulus and responds with a signal
- receiver sees signal and responds with action
- reward if action matches stimulus
- solution: require that some stimuli MUST be accepted (rejected) → pressure for expressiveness
- looks like interesting extension of signalling games to aggregating signals

Thank you

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