Modeling **overspecification** as uncertainty about feature uniqueness

UNIVERSITÄT DES SAARLANDES

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Pros & Comps Workshop

Ljubljana, 03.08.23

Introduction

- Many different ways of referring to objects

Introduction

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  - jacket?
  - blue jacket?
  - item of clothing?

Introduction

- Many different ways of referring to objects
- Depends on the context
  - other objects in the visual scene

Introduction

- Many different ways of referring to objects
- Depends on the context
  - other objects in the visual scene
- **Overspecification**
  - mentioning more attributes than is necessary
  - saying “blue jacket” when it’s the only jacket
- A puzzle for pragmatics
  - Grice’s maxim of quantity: say as much as is required and no more
  - if more is said, comprehender may draw additional inferences (e.g., Kravtchenko & Demberg, 2017)
  - however, people often overspecify

Outline

1. Background
   a. evidence from Psycholinguistics
   b. Rational Speech Act (RSA) Framework
   c. existing model of overspecification: Continuous Semantics RSA
2. Our proposed model of overspecification
   a. Motivation
   b. Model
3. Experiment
4. Discussion

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Background

What leads to overspecification?

- more overspecification with color over size
  - but can change if differences in size are made bigger and differences in color smaller (van Gompel et al., 2014)

Background

What leads to overspecification?

- more overspecification with color over size
- atypical properties are mentioned more often (Westerbeek et al., 2015)

“banana”

“**blue** banana”

Background

What leads to overspecification?

- more overspecification with color over size
- atypical properties are mentioned more often
- increased scene variation leads to more overspecification (Koolen et al., 2013)

“fan”

“**blue** couch”

Background

What leads to overspecification?

- more overspecification with color over size
- atypical properties are mentioned more often
- increased scene variation leads to more overspecification (Koolen et al., 2013)

These are **circumstances** under which people tend to overspecify. What are the **reasons** they do it?

Outline

How do we model overspecification?

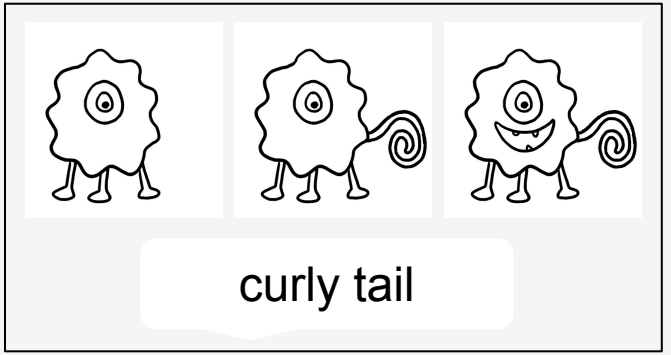
- a computational model should formalize a theory about **reason(s) for overspecification**
- Degen et al. (2020) propose a model of overspecification in the Rational Speech Act Framework

Rational Speech Act (RSA)

- A Bayesian framework for modeling pragmatic reasoning
- Listener and speaker recursively reason about each other to arrive at a shared interpretation
  - speaker's task: choose utterance ***u*** to describe object ***o***
  - listener's task: pick out object ***o*** based on the utterance ***u***

Rational Speech Act (RSA)

Literal listener $\mathbf{L_0}$ hears an utterance u. $\mathbf{L_0}$ has a probability distribution of over objects **o** given the utterance **u**:



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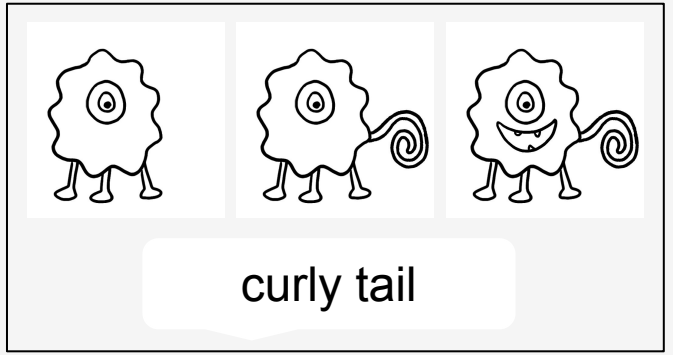
is the utterance true of the object?

Prior: how likely an object is to be referred to a priori



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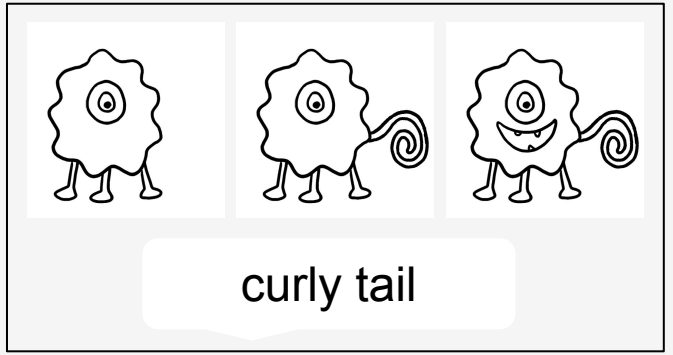
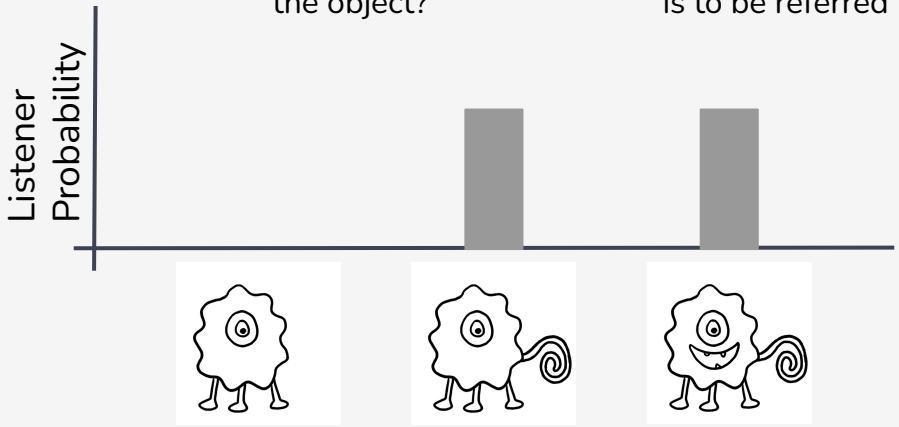
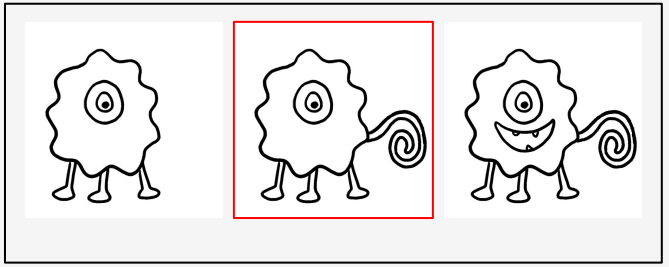




Rational Speech Act (RSA)

Pragmatic speaker $\mathbf{S_1}$ chooses an utterance ***u*** such that $\mathbf{L_0}$ is most likely to identify the correct referent while minimizing utterance cost:



$$L_0(o|u) \propto P(u|o) \cdot P(o)$$

$$S_1(u|o) \propto exp(\alpha \cdot (logL_0(o|u) - Cost(u))$$

e.g., utterance length of complexity

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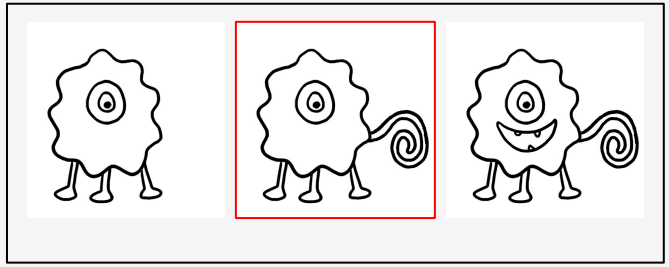

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in standard RSA, no overspecification advantage: if two utterances are true of an object, the longer one is never more likely

e.g., utterance length of complexity

Continuous Semantics RSA

- Degen et al. (2020)'s model of overspecification
  - relaxes boolean semantics of P(u|o)
  - values between 0 and 1 are now possible
    - e.g. an object can be 0.9 green or 0.8 big

$$L_0(o|u) \propto P(u|o) \cdot P(o)$$

not just 0 or 1 anymore; values in between possible

Continuous Semantics RSA

- Degen et al. (2020)'s model of overspecification
  - relaxes boolean semantics of P(u|o)
  - values between 0 and 1 are now possible
    - e.g. an object can be 0.9 green or 0.8 big
- Lower semantic values are considered "more noisy" and less informative
- Allows for overspecification because adding less noisy modifiers adds information
- Potential interpretation of semantic values:
  - how easy it is to verify that a property holds for an object (e.g. that an object is green vs that it is big)

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Our model: motivation

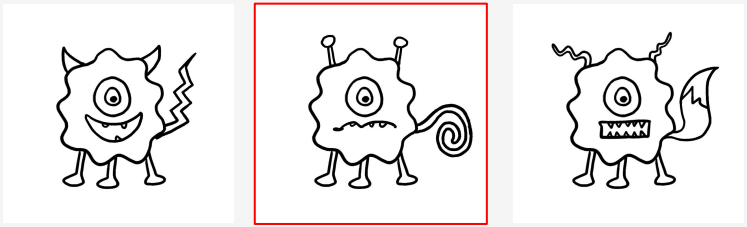
- Continuous Semantics RSA is a model of *semantics of words*
  - how well descriptions apply to objects
- Are there also non-semantic reasons for overspecifying?
  - visual complexity?
- Tendency to avoid extensive visual search
- Participants sometimes begin speaking before having scanned the whole scene (Elsner et al., 2018)
- Participants may rely on quick heuristics (Koolen et al., 2013)

Our model: motivation

- Standard RSA includes speaking effort: if production is costly, longer utterances will be less likely
- We propose that there may also be **utterance planning effort**
  - cost associated with computing an optimal utterance
  - effortful to determine a minimal unique set of target properties
- Overspecification results from tendency to **avoid extensive visual search**
  - speaker allows for the possibility that a given feature may be present elsewhere in the visual scene

Our model (Mirage RSA)

- We operationalize uncertainty about feature uniqueness via a process we'll call **miraging**
- In addition to objects actually present in the scene, the speaker allows for the possibility that additional objects are present that share some of the target's features



actually present

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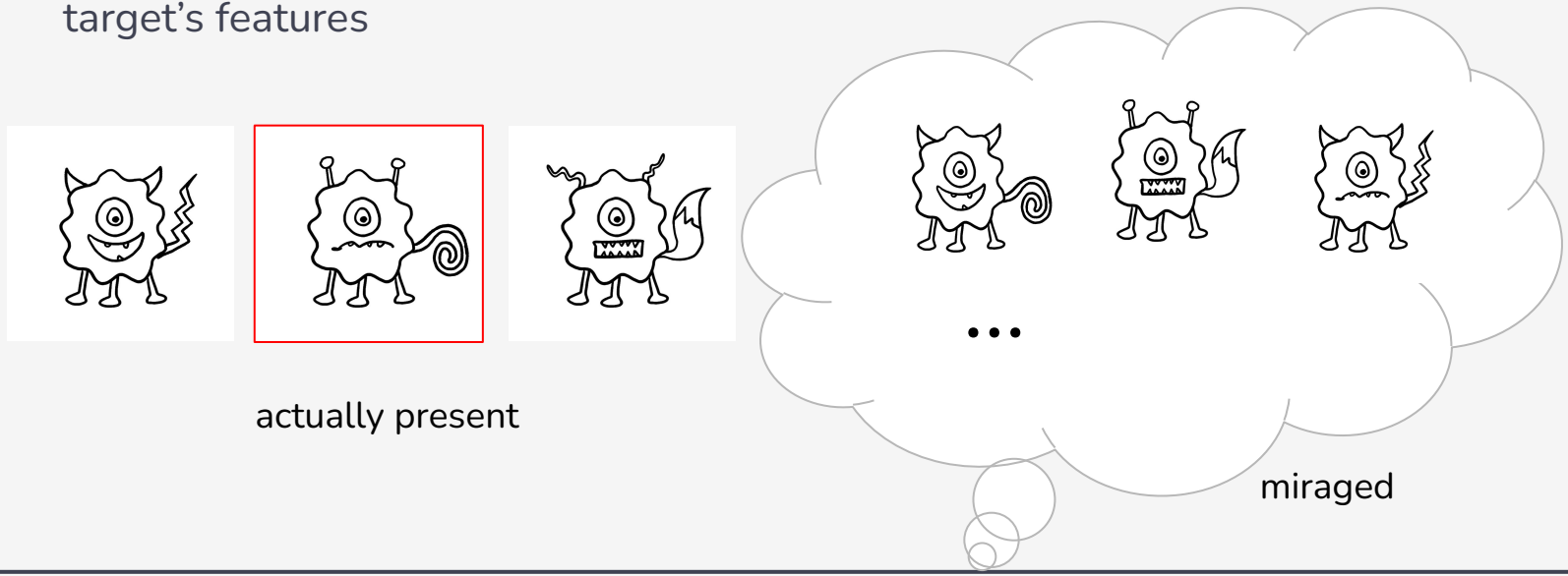

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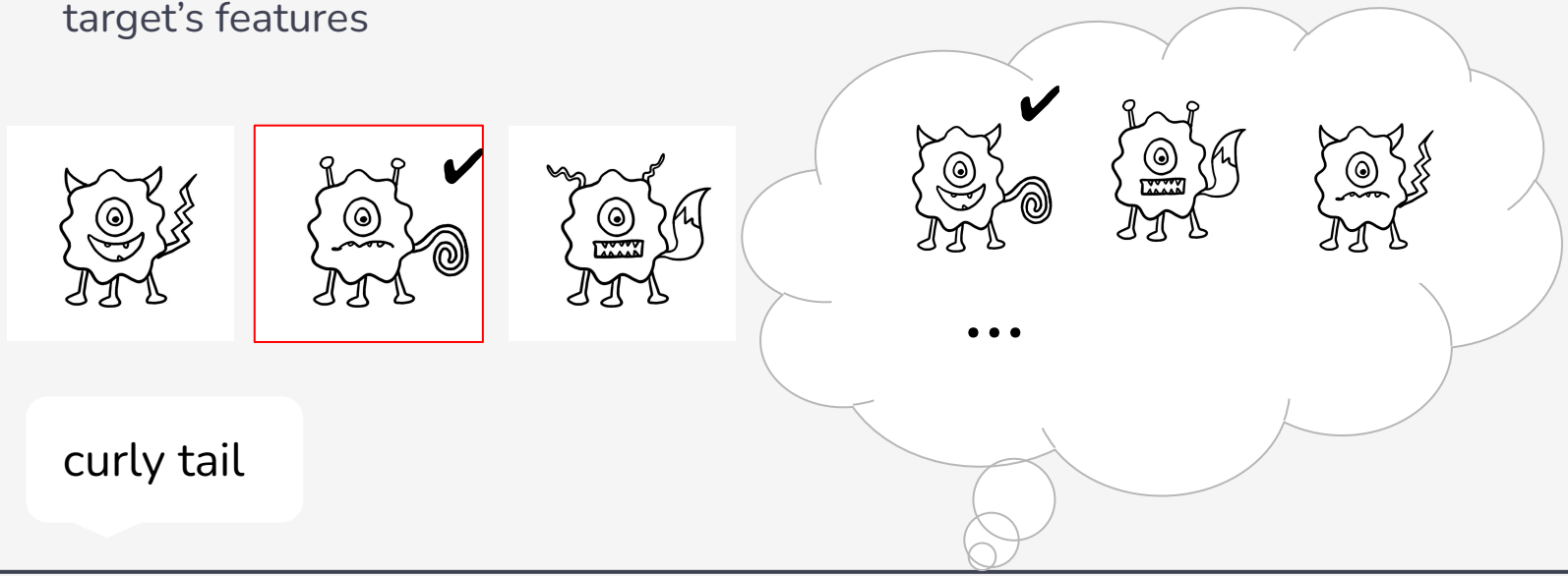

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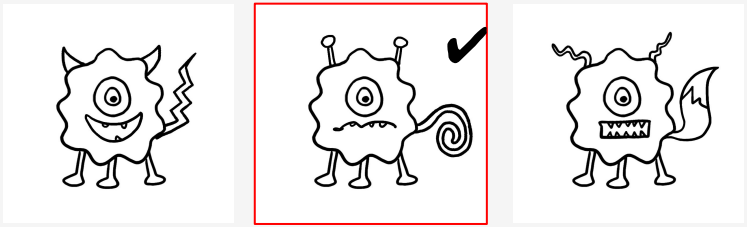
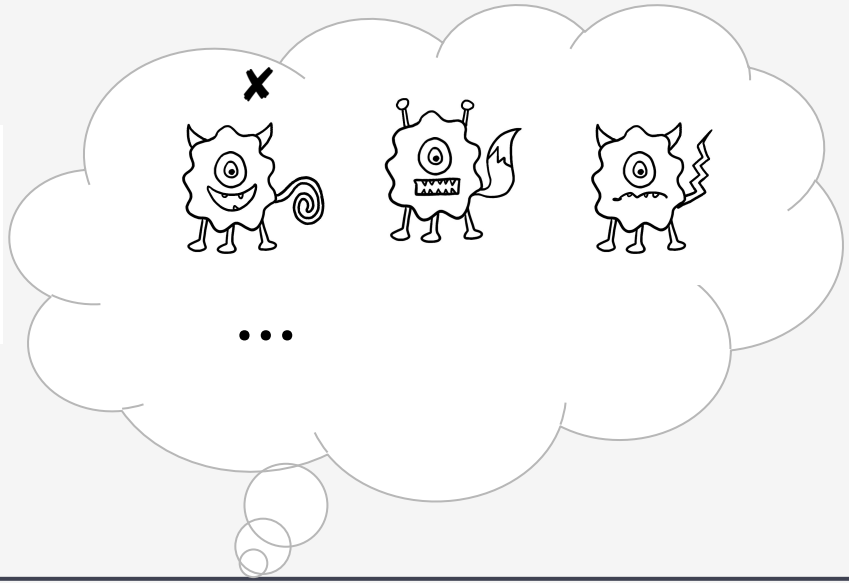


curly tail and sad expression



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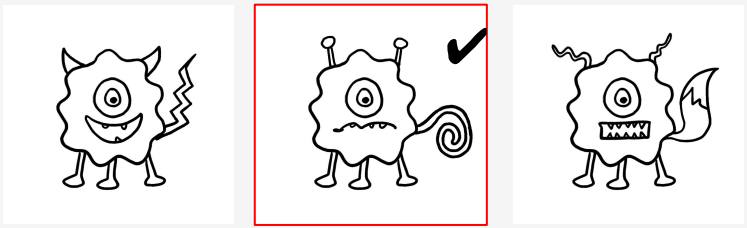
- the set of miraged items includes **all strict subsets** of target features combined with distractor features
  - included in the gist of the scene



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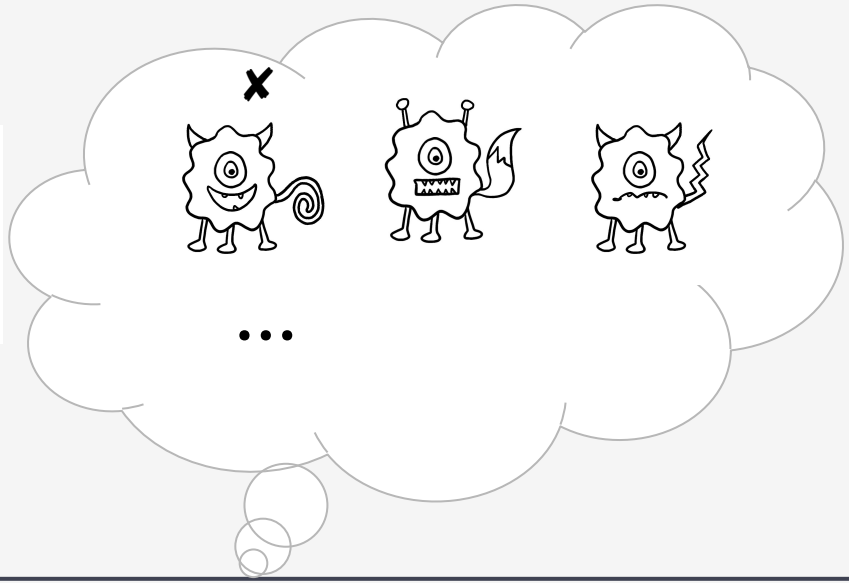

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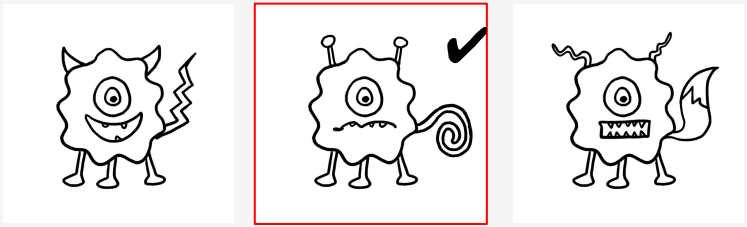
- additionally, it includes combinations of target features with **unseen "other" features**



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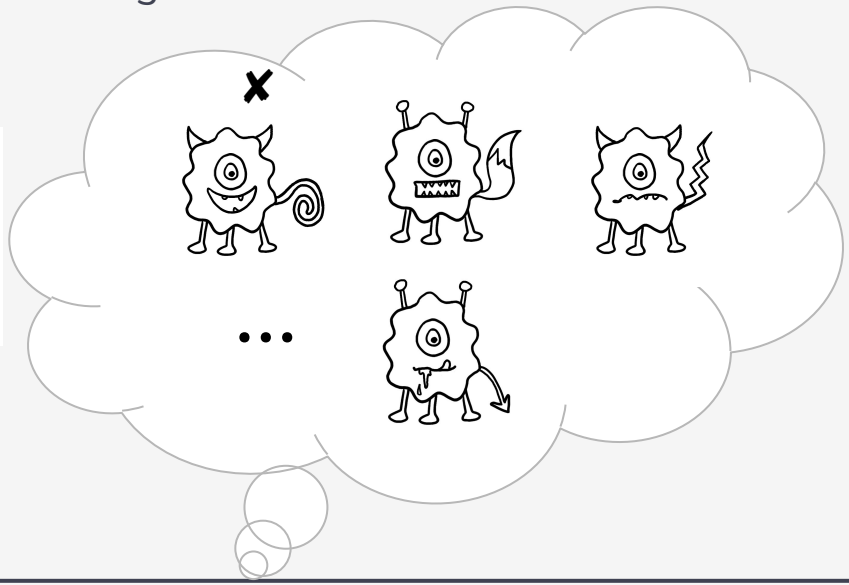

Our model (Mirage RSA)

- overspecified utterances become more likely because they rule out more mirage competitors

$$L_0(o|u) \propto P(u|o) \cdot P(o)$$

the set of objects includes mirage competitors

the prior probability of miraged objects is determined by the hyperparameter **m** (miraging weight, 0-1)
higher miraging weight → more miraging

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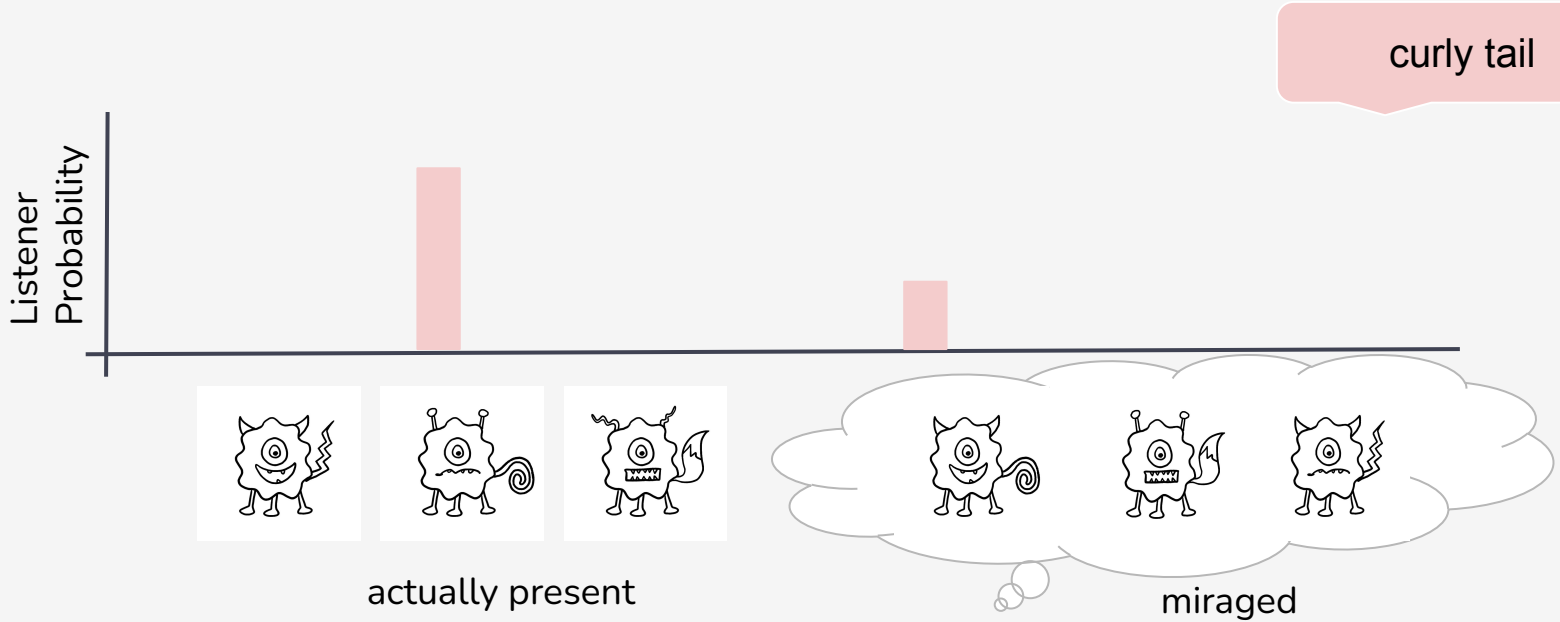

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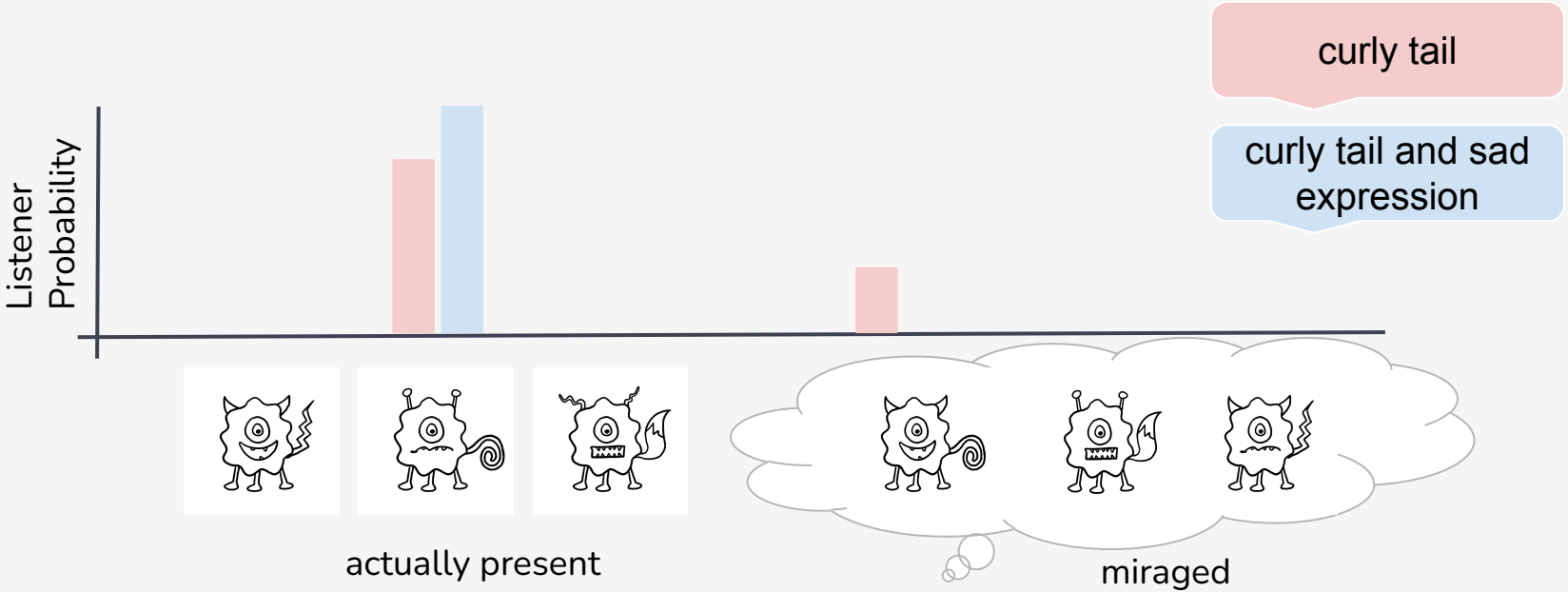

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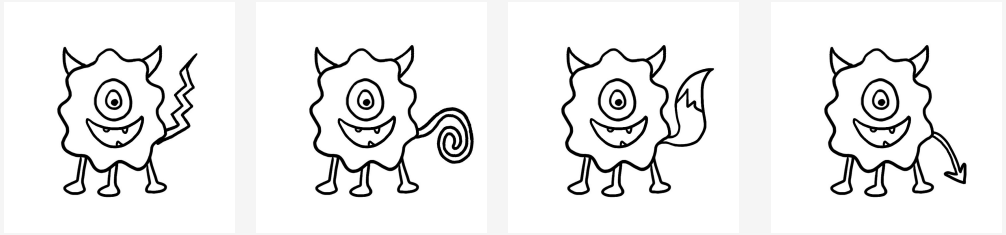
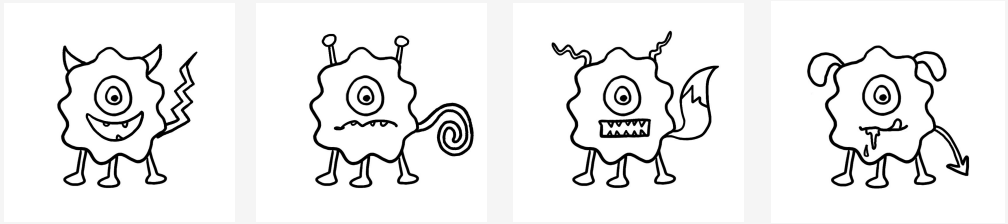
Experiment

- High scene complexity makes it hard to compute an optimal referring expression, leading to overspecification
- Therefore, if we lower scene complexity, making differences easier to see, overspecification should decrease
  - corresponds to reducing miraging weight ***m***

Experiment



Low variation (1 feature different)

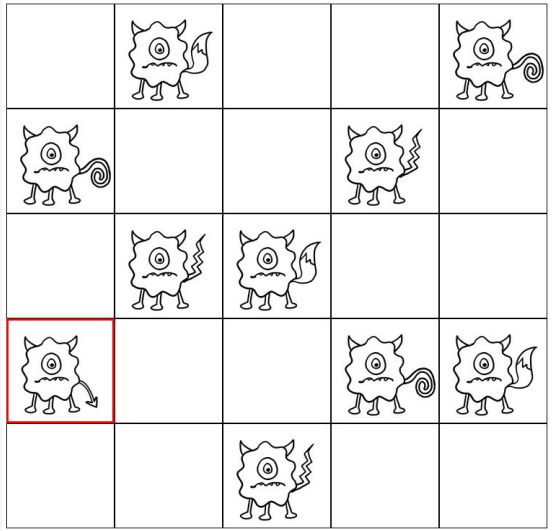


High variation (3 features different)

Continuous Semantics RSA prediction:
more overspecification in the high variation condition because there are more features whose labels are noisy

Mirage RSA prediction:
more overspecification in the high variation condition because more distinct mirage distractors are generated

Experiment



unsorted

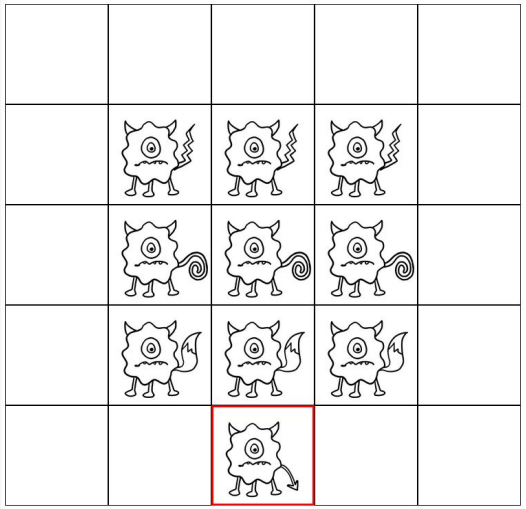
sorted

Continuous Semantics RSA prediction:
no difference (exact same features present)

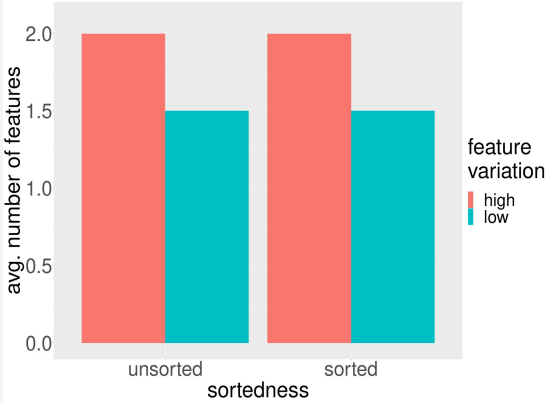
Mirage RSA prediction:
more overspecification in the unsorted condition because differences are harder to see (higher miraging weight **m**)

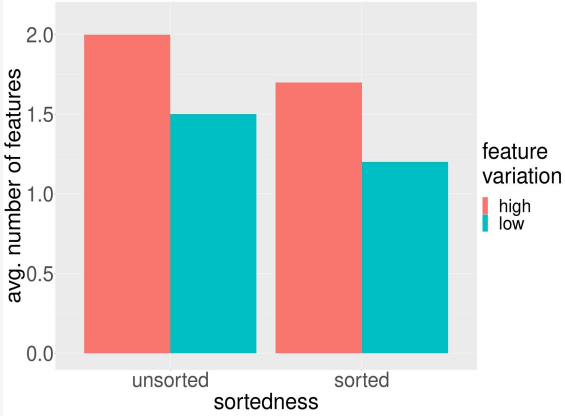
Experiment

- Participants were randomly assigned to either the sorted or the unsorted condition
- Each participant saw 6 items in the high variation and 6 in the low variation condition
- They were asked to describe the monster in the red box so that a participant in a future study can identify it based on the description



Predictions





Continuous Semantics RSA:

- effect of feature variation
- **no** effect of sortedness

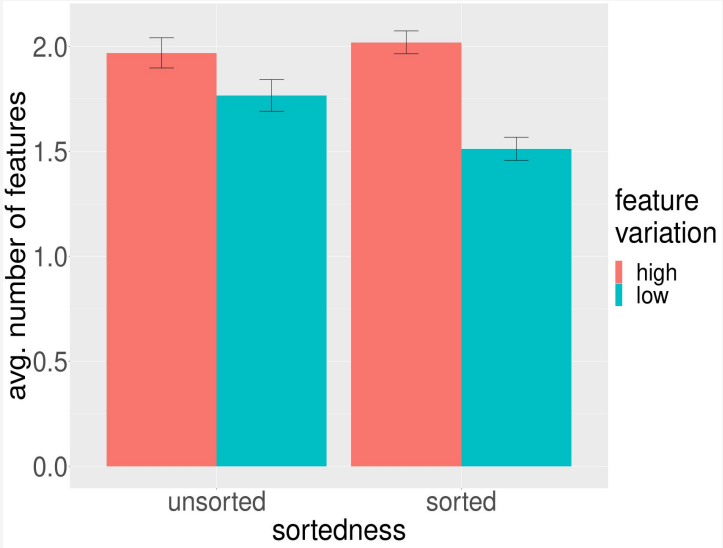
Mirage RSA (our model):

- effect of feature variation
- effect of sortedness

Experiment: Results

We find:

- an effect of feature variation: more overspecification in the high feature variation condition
- no main effect of sortedness
- an interaction between feature variation and sortedness
  - sorting appears to reduce overspecification only in the low variation condition
- findings do not exactly match the predictions of either model
  - some evidence for the miraging model in the low variation condition



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  - in addition, not instead of, the Continuous Semantics account
- Overspecification emerges from **utterance planning cost**:
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  - borne out only in the low variation condition
  - further investigation needed

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- Model prediction: when differences are made easier to see, overspecification goes down
  - borne out only in the low variation condition
  - further investigation needed
- A lot of individual variation: from always overspecifying to never overspecifying
  - influenced by traits like reasoning skills and verbosity?
  - modeling could be explored in future work

Acknowledgements

Joint work with

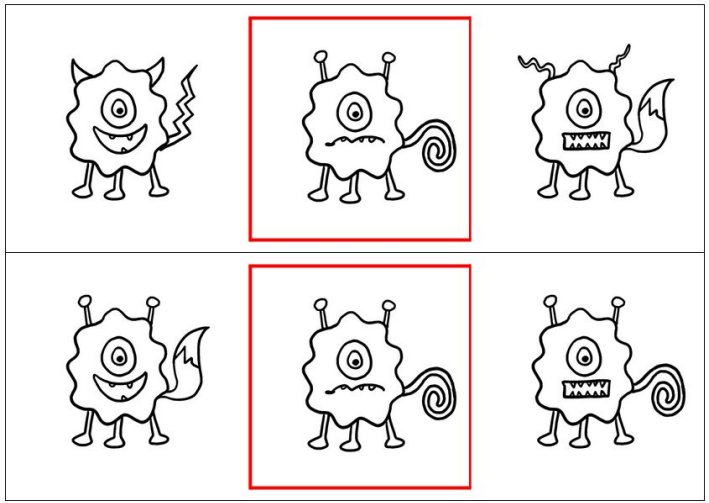
Dr. Jia E. Loy

Prof. Vera Demberg

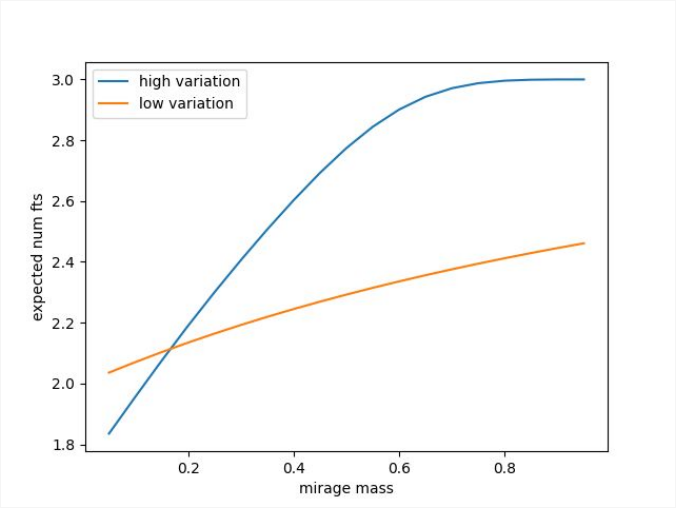
We gratefully acknowledge funding through the ERC Starting Grant "Individualized Interaction in Discourse".

European Research Council
Established by the European Commission

Model Behavior

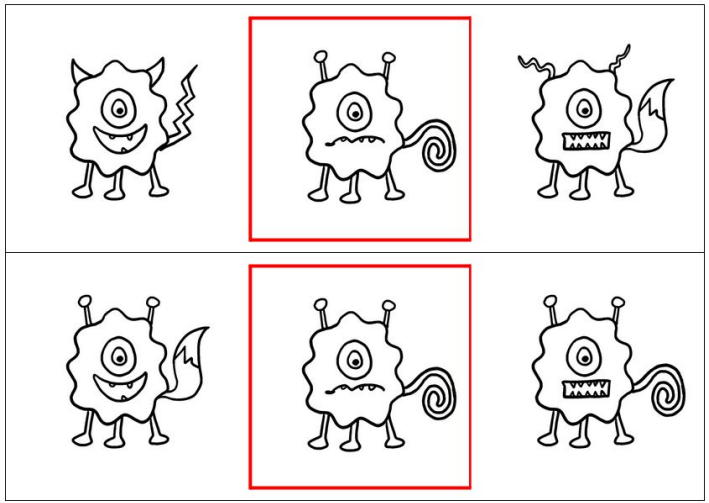


High and low variation conditions



Expected number of features (1-3) as a function of mirage mass, assuming zero utterance cost

Model Behavior



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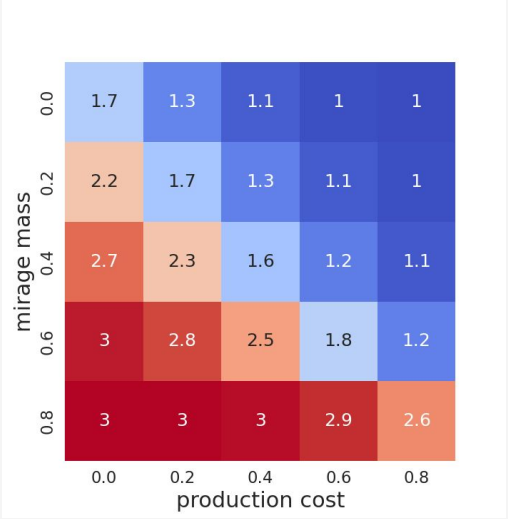

Expected number of features (1-3) in the high variation condition
as a function of mirage mass and production cost