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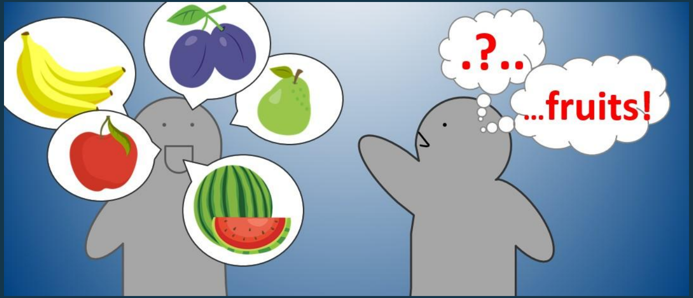
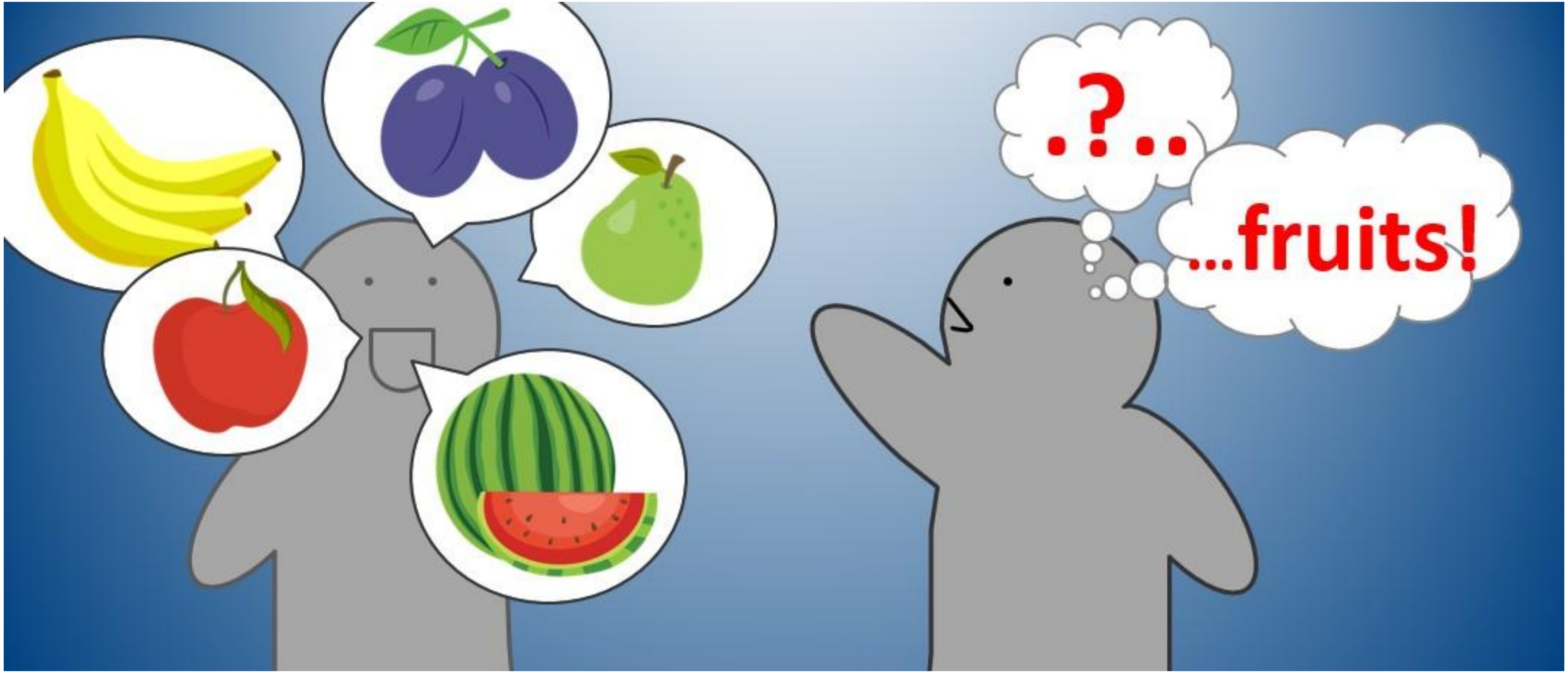
Kobrock, K., Ohmer, X., Bruni, E., and Gotzner, N. (2023)

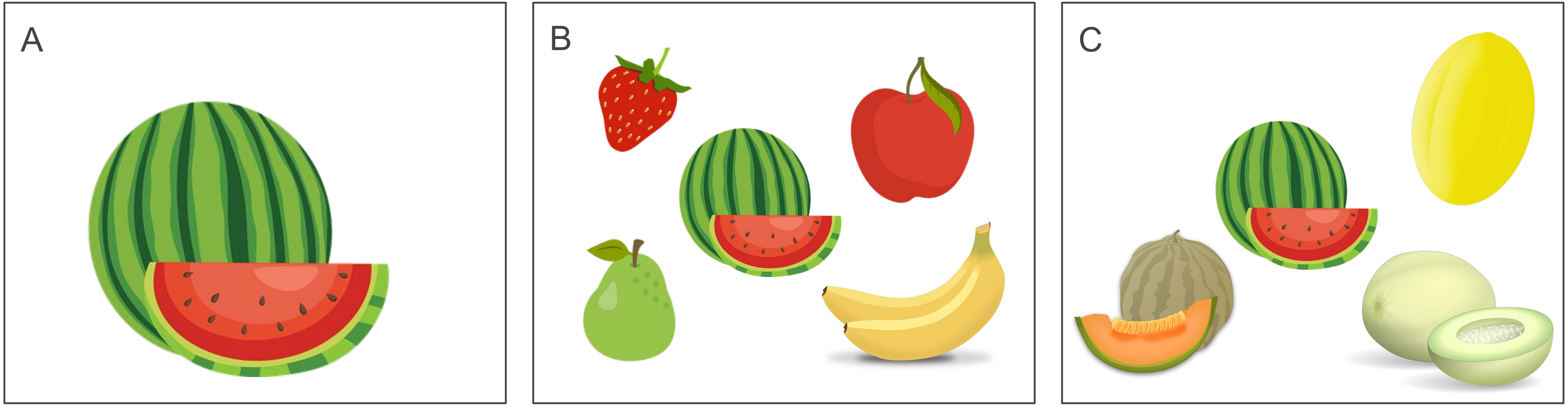


Pragmatics in referential communication

An investigation of concept communication and the role of pragmatics with an emergent communication game


.?..
...fruits!

Levels of abstraction shaped by context



“watermelon”

“melon”

“fruit”

“food”

specific

generic

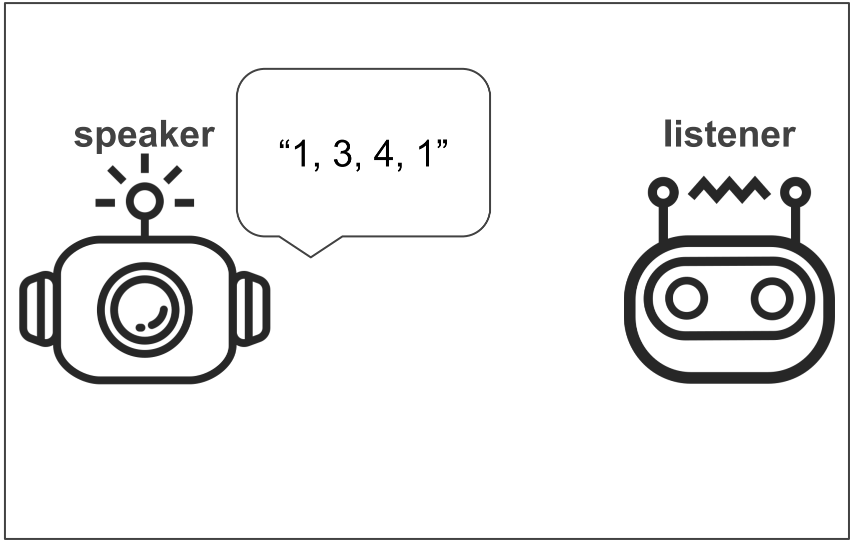
“melon”

“watermelon”

coarse context *fine*

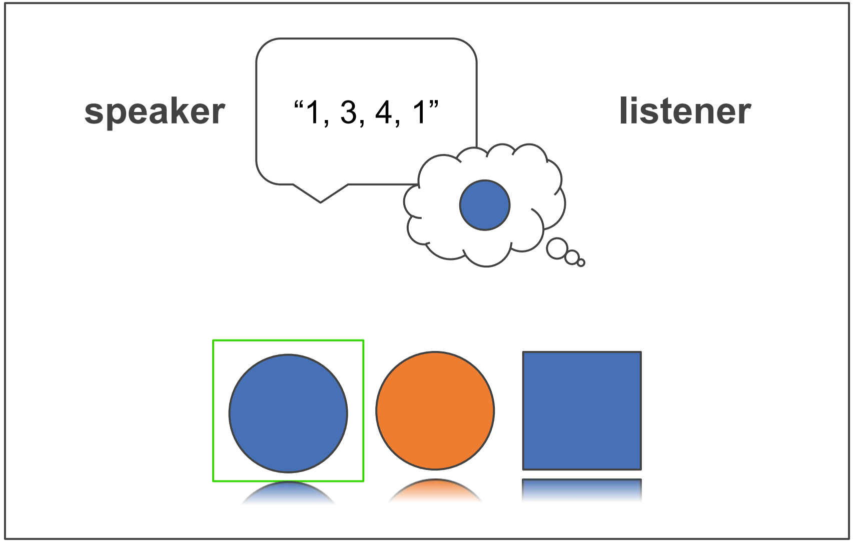
Paradigm and set-up

1) Emergent communication



e.g., Lazaridou et al. (2017), Ohmer et al. (2022)

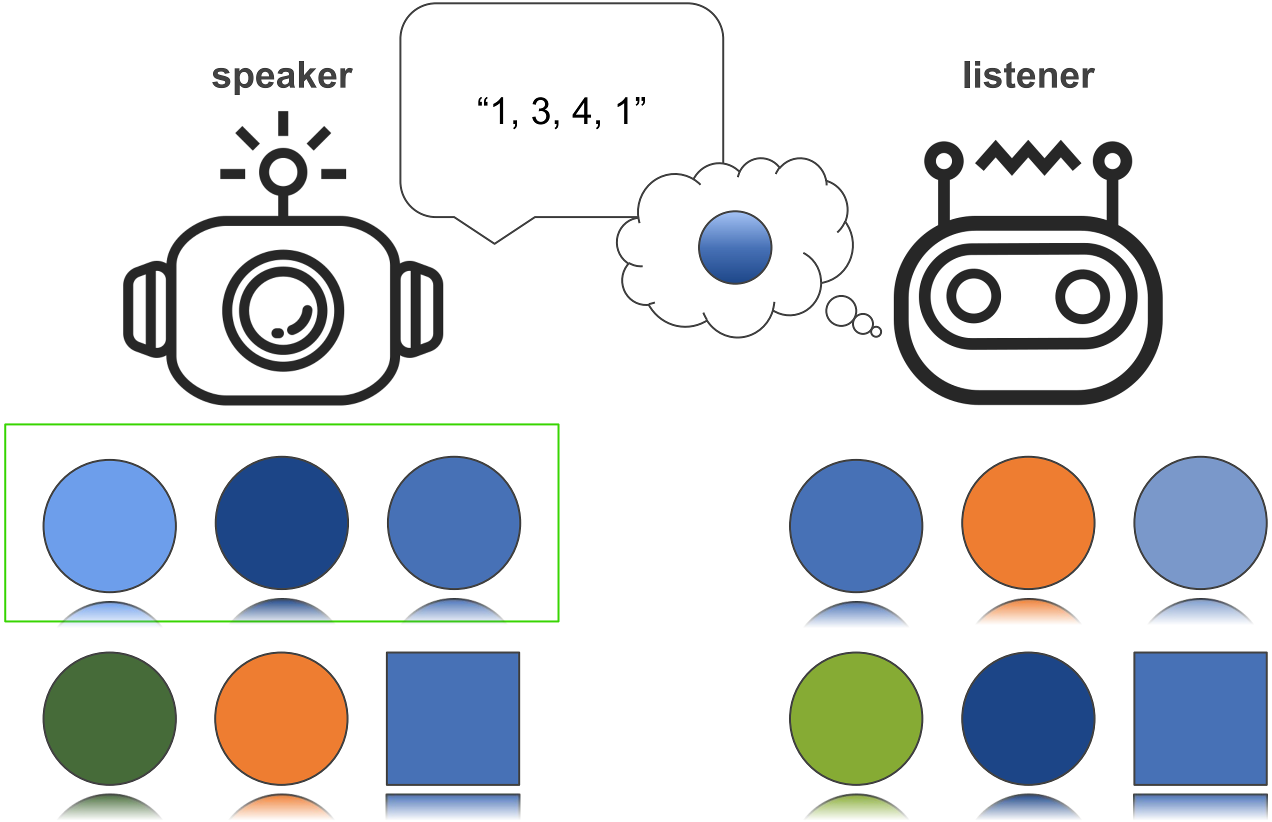
2) Reference game



e.g., Franke & Degen (2016)

Concept-level reference game

Mu & Goodman (2021)



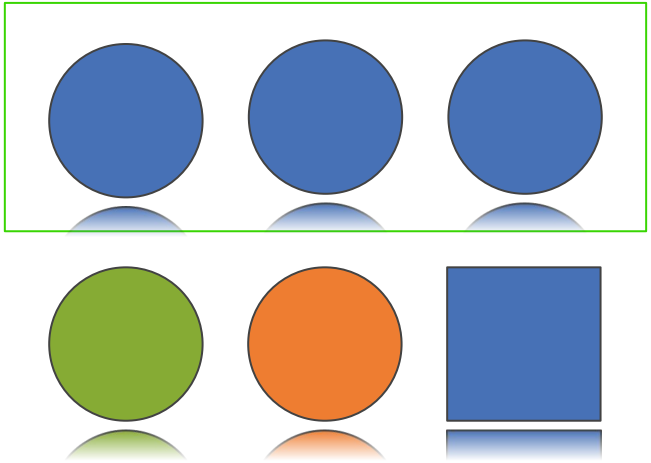
Symbolic dataset: Objects consist of *n* attributes which each can take *k* values.

Dataset manipulates concept level and context

→ The more attributes are **fixed**, the more ***specific*** the concept.
→ The more fixed attributes are **shared** between targets and distractors, the ***finer*** the context.

Concept x context conditions

A) **specific concept, fine context:**



```
Set notation:
Colors = {blue, green, orange}
Shapes = {circle, square, triangle}
```

target concept: “blue circle”

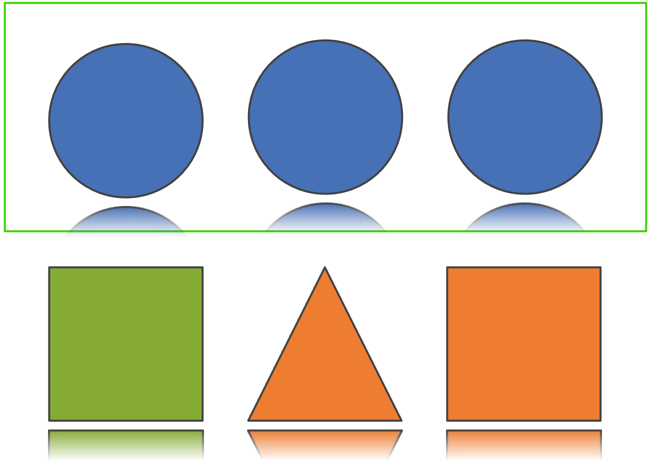
`{(blue, circle)}`

distractor concept: “blue shapes which are no circles and circles which are not blue”

`{(blue, square), (blue, triangle), (orange, circle), (green, circle)}`

Concept x context conditions

B) **<u>specific concept, coarse context:</u>**

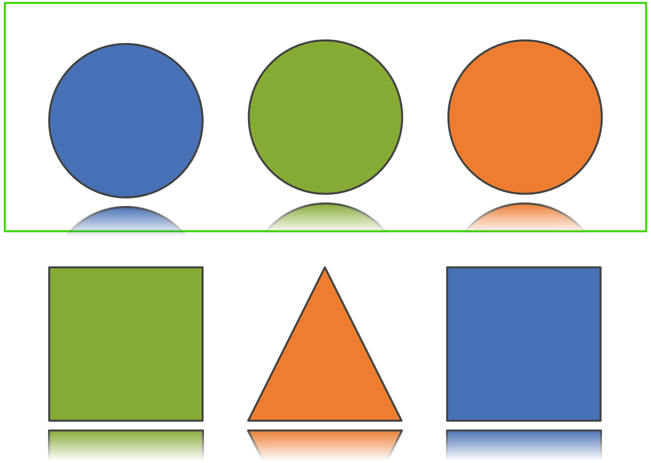


target concept: “blue circle”
`{(blue, circle)}`

distractor concept: “all that is not blue or a circle”
`{(green, square), (orange, square), (green, triangle), (orange, triangle)}`

Concept x context conditions

C) **generic concept, coarse context:**



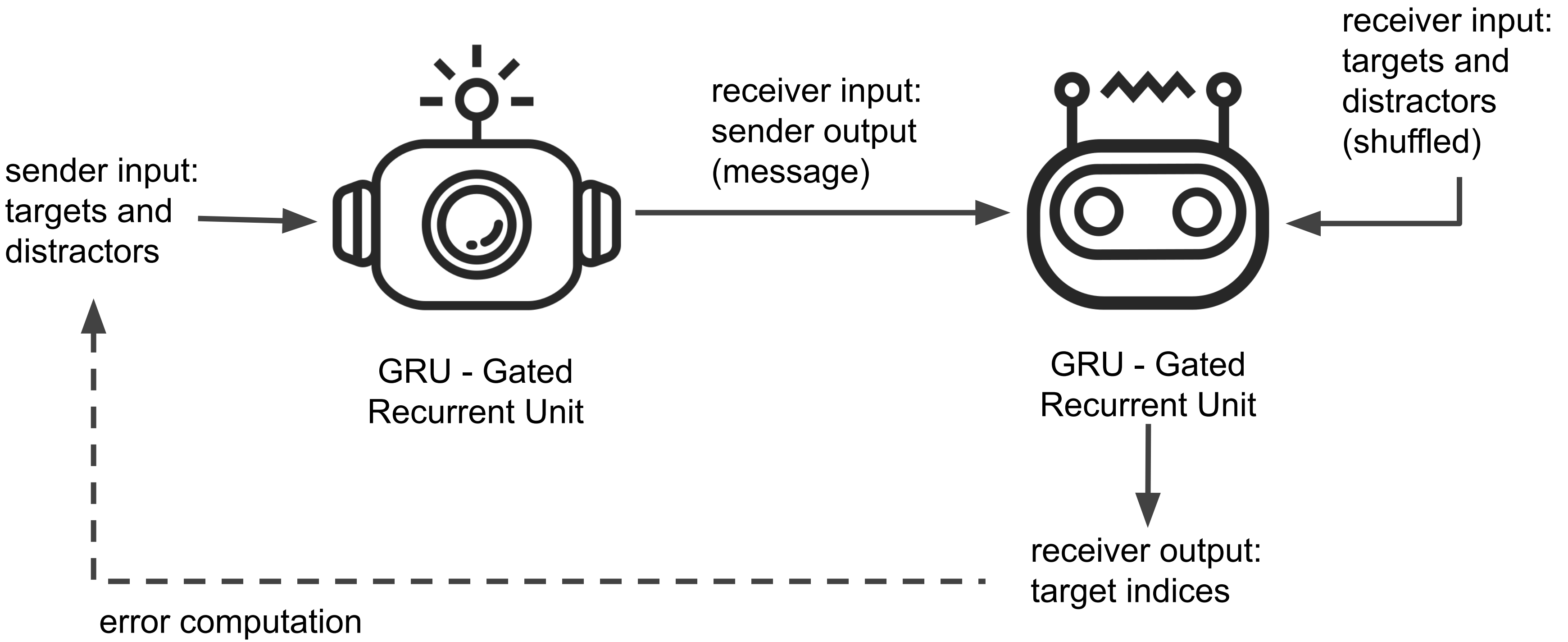
target concept: “circle”
`{(blue, circle), (green, circle), (orange, circle)}`

distractor concept: “all that is not a circle”
`{(blue, square), (green, square), (orange, square), (blue, triangle), (green, triangle), (orange, triangle)}`

Training

Speakers and listeners

using EGG implementation (Kharitonov et al., 2019)



Which communicative strategies do speakers follow when referring to concepts at different levels of abstraction?

Hypotheses

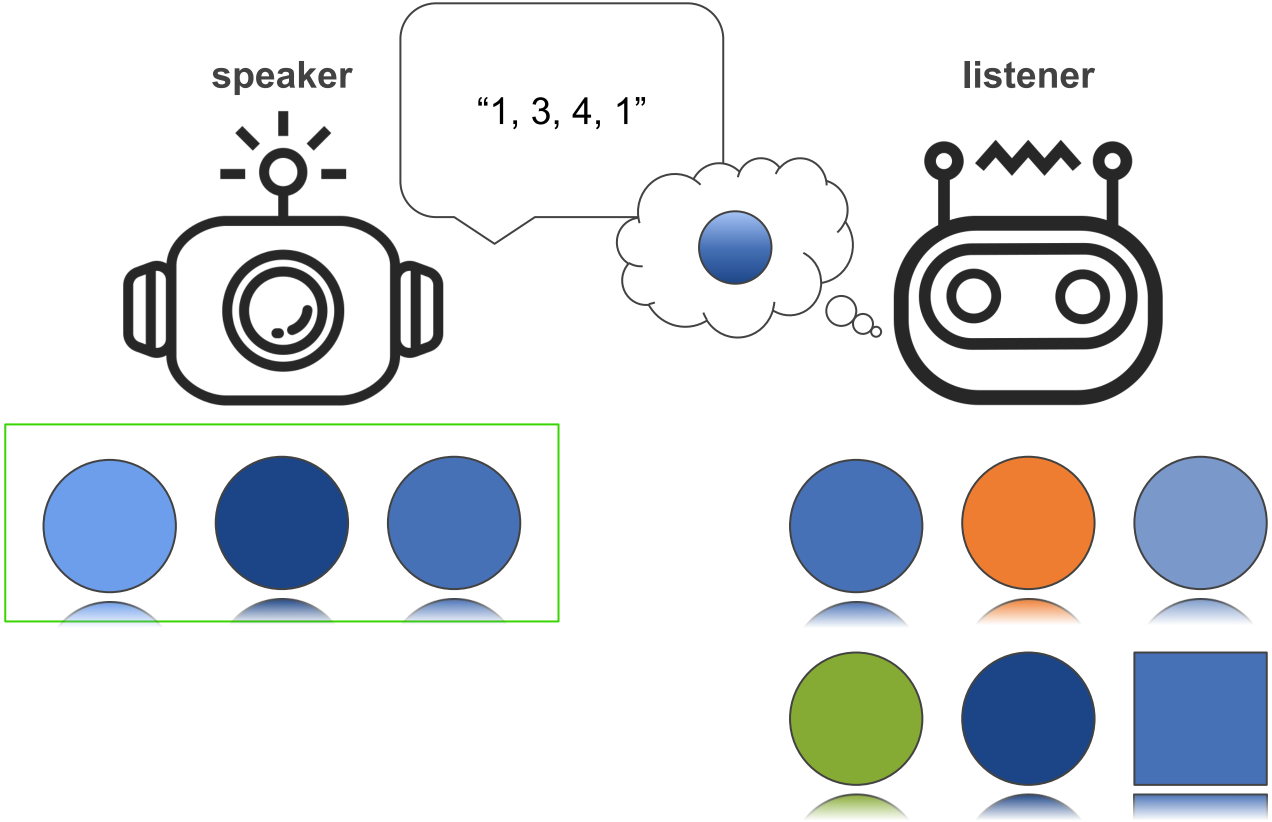
Baseline: Context-unaware literal agents (L) have to communicate all relevant attributes to be successful, thus may be overinformative (non-pragmatic baseline).

• **H1: Context-aware literal agents (L-aware)** can communicate fewer than all attributes and let uncertainty be resolved by context (context-based pragmatics).

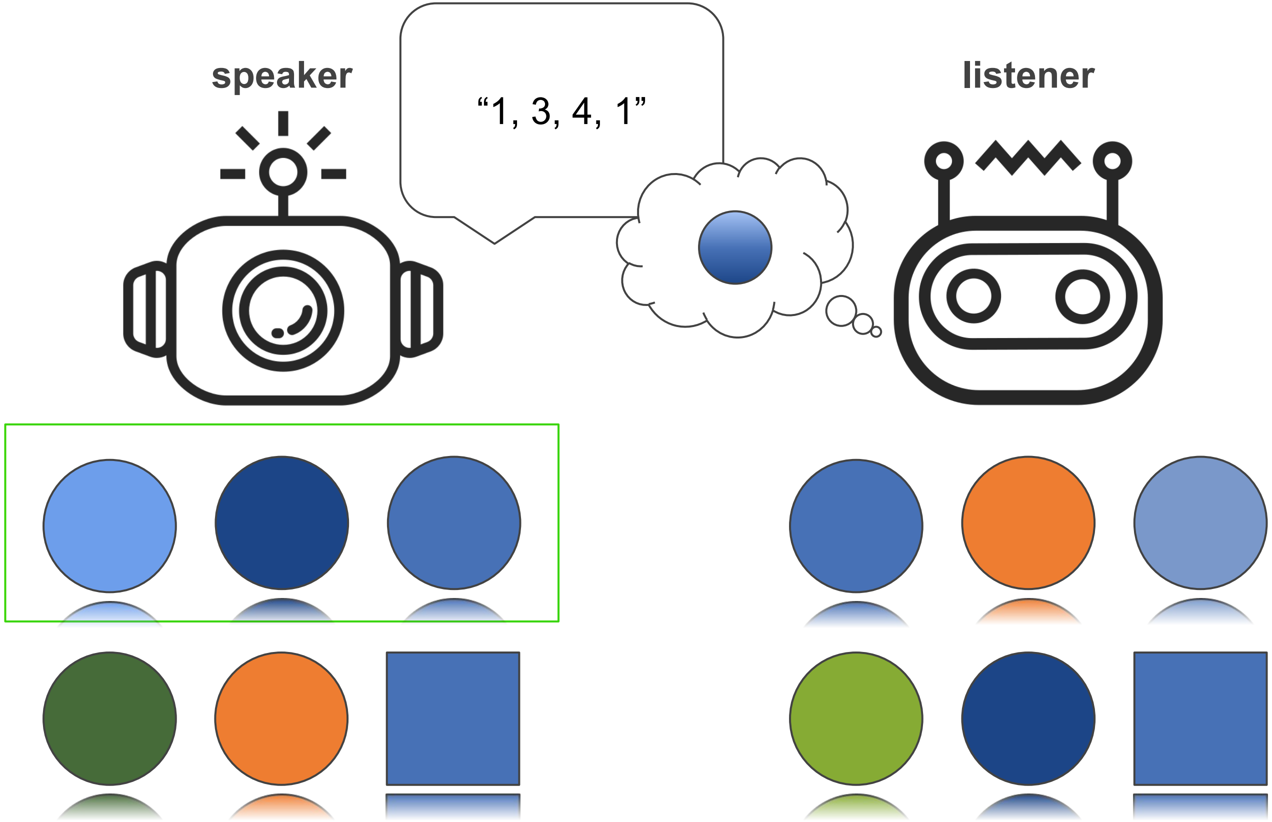
• **H2: L-aware + utterance cost** will further reduce overinformation because communicating fewer attributes becomes beneficial (context-based pragmatics + implicit abstraction).

• **H3: L + RSA** will increase the agents' performance through additional recursive reasoning of the speaker (reasoning about intentions).

Context-unaware



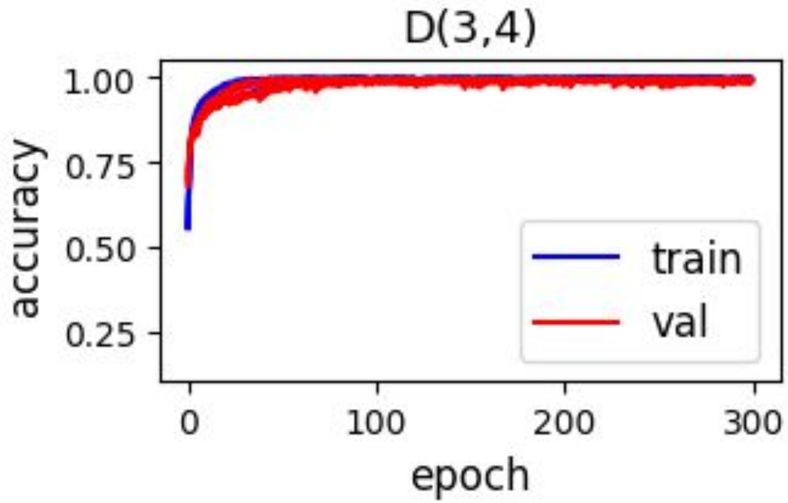
Context-aware



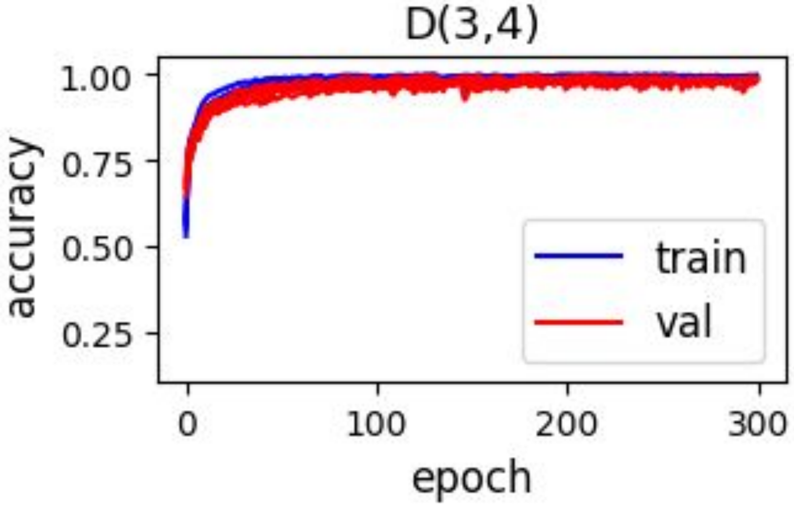
Do the agents learn to successfully communicate?

Accuracies over time

Context-unaware

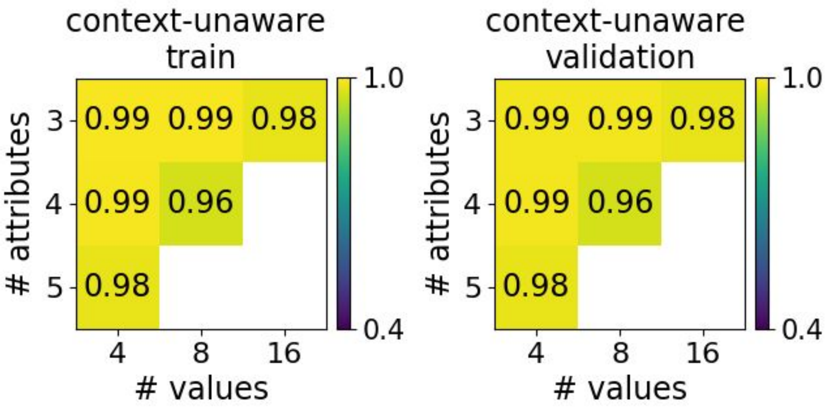


Context-aware

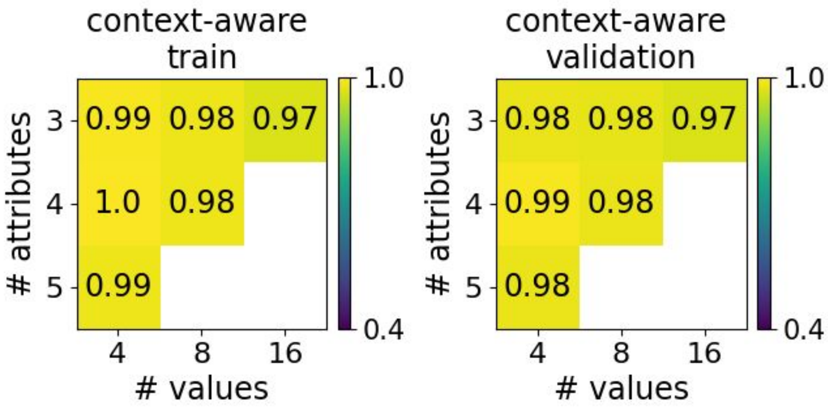


Final accuracies

Context-unaware



Context-aware



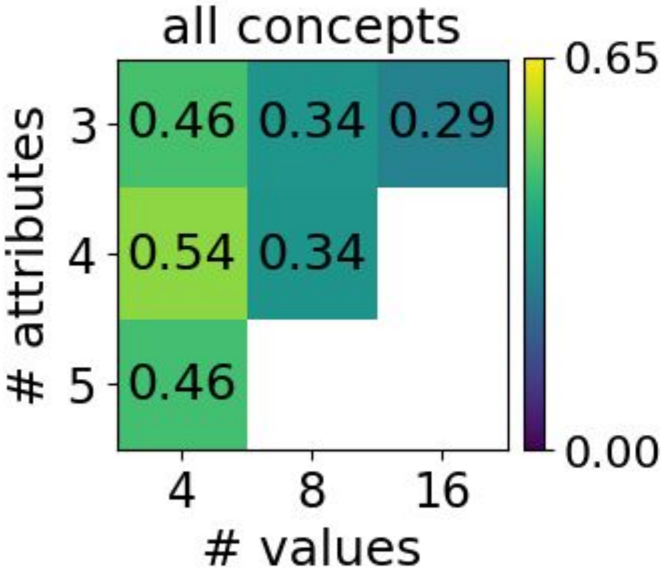
→ trained five runs on six datasets: D(3,4), D(3,8), D(3,16), D(4,4), D(4,8), D(5,4)

Do agents learn to **efficiently** communicate?

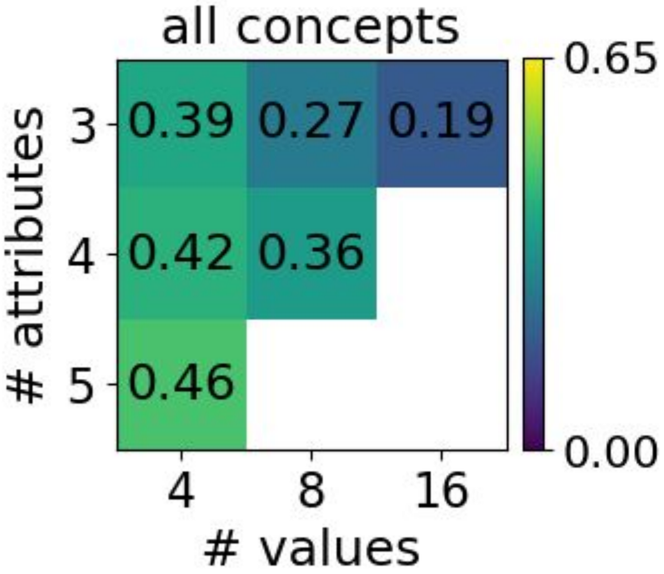
Compositionality: Topographic similarity

Brighton & Kirby (2006)

Context-unaware

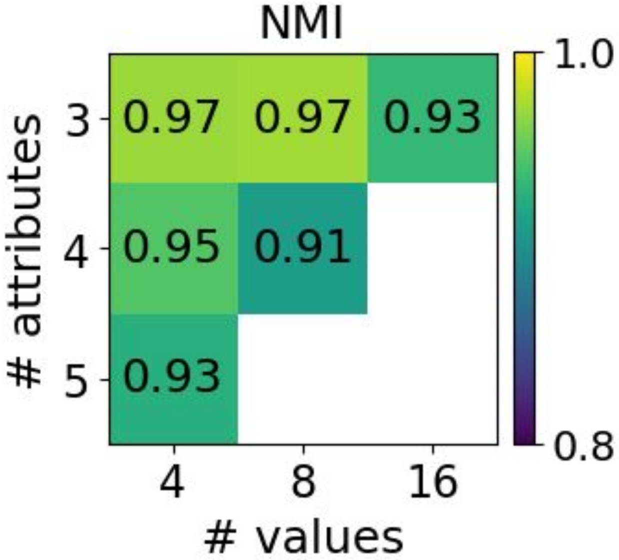


Context-aware

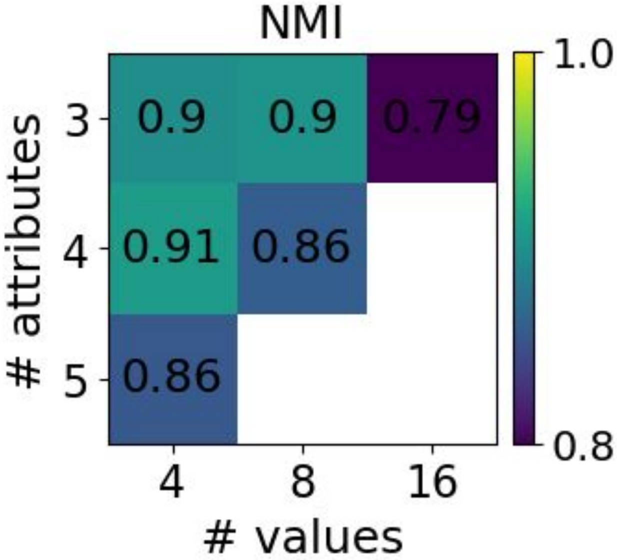


Informativity: Normalized mutual information (NMI)

Context-unaware



Context-aware



Do agents learn to **reason about the context** when deciding on the referring expression’s appropriate level of abstraction?

Qualitative analysis of the messages - context-unaware

object	fixed indices	context condition	message
[0, 2, 1]	[1, 1, 1]	0	[2, 2, 2]
[0, 2, 1]	[1, 1, 1]	0	[2, 2, 2]
[0, 2, 1]	[1, 1, 1]	0	[2, 2, 2]
[0, 2, 1]	[1, 1, 1]	1	[2, 2, 2]
[0, 2, 1]	[1, 1, 1]	1	[2, 2, 2]
[0, 2, 1]	[1, 1, 1]	1	[2, 2, 2]
[0, 2, 1]	[1, 1, 1]	2	[2, 2, 2]
[0, 2, 1]	[1, 1, 1]	2	[2, 2, 2]
[0, 2, 1]	[1, 1, 1]	2	[2, 2, 2]

object	fixed indices	context condition	message
[3, 1, 2]	[1, 1, 1]	0	[13, 13, 13]
[3, 1, 2]	[1, 1, 1]	0	[13, 13, 13]
[3, 1, 2]	[1, 1, 1]	0	[13, 13, 13]
[3, 1, 2]	[1, 1, 1]	1	[13, 13, 13]
[3, 1, 2]	[1, 1, 1]	1	[13, 13, 13]
[3, 1, 2]	[1, 1, 1]	1	[13, 13, 13]
[3, 1, 2]	[1, 1, 1]	2	[13, 13, 13]
[3, 1, 2]	[1, 1, 1]	2	[13, 13, 13]
[3, 1, 2]	[1, 1, 1]	2	[13, 13, 13]

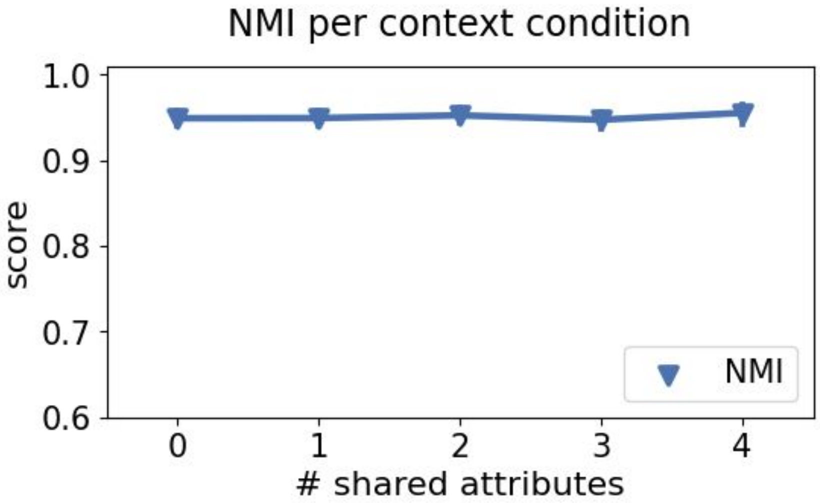
Qualitative analysis of the messages - context-aware

object	fixed indices	context condition	message
[0, 3, 2]	[1, 1, 1]	0	[11, 1, 9]
[0, 3, 2]	[1, 1, 1]	0	[11, 1, 14]
[0, 3, 2]	[1, 1, 1]	0	[11, 1, 1]
[0, 3, 2]	[1, 1, 1]	1	[1, 1, 1]
[0, 3, 2]	[1, 1, 1]	1	[11, 1, 1]
[0, 3, 2]	[1, 1, 1]	1	[1, 1, 9]
[0, 3, 2]	[1, 1, 1]	2	[1, 1, 1]
[0, 3, 2]	[1, 1, 1]	2	[1, 1, 1]
[0, 3, 2]	[1, 1, 1]	2	[1, 1, 1]

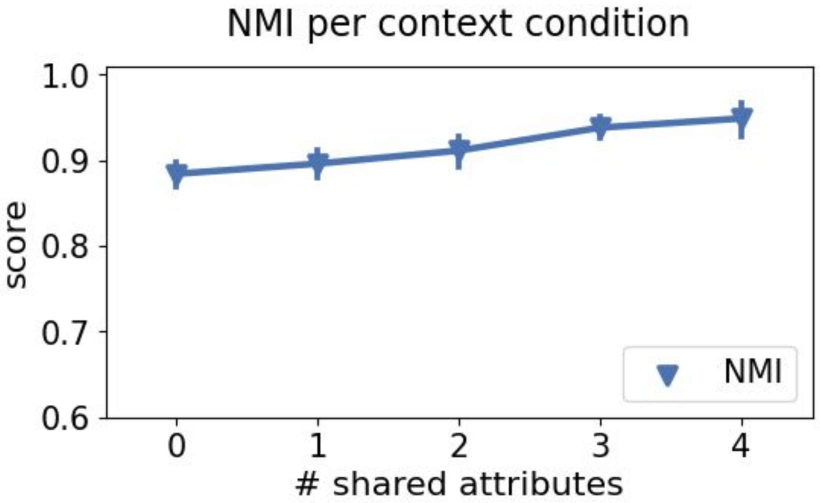
object	fixed indices	context condition	message
[2, 3, 1]	[1, 1, 1]	0	[6, 13, 10]
[2, 3, 1]	[1, 1, 1]	0	[6, 13, 10]
[2, 3, 1]	[1, 1, 1]	0	[6, 13, 10]
[2, 3, 1]	[1, 1, 1]	1	[13, 6, 3]
[2, 3, 1]	[1, 1, 1]	1	[6, 13, 10]
[2, 3, 1]	[1, 1, 1]	1	[6, 13, 10]
[2, 3, 1]	[1, 1, 1]	2	[13, 10, 13]
[2, 3, 1]	[1, 1, 1]	2	[13, 10, 13]
[2, 3, 1]	[1, 1, 1]	2	[13, 10, 13]

Informativity: NMI per context condition

Context-unaware



Context-aware



→ Context-aware: The ***finer*** the context, the **more** one-to-one mappings and the ***coarser*** the context, the **fewer** one-to-one mappings (similar to Hawkins et al., 2018).

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Thank you!

Any questions?

Short summary

Agents learn to successfully (and somewhat efficiently) communicate in a concept-level reference game.

The mere presence of context drives its use in communication (without further incentives).

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