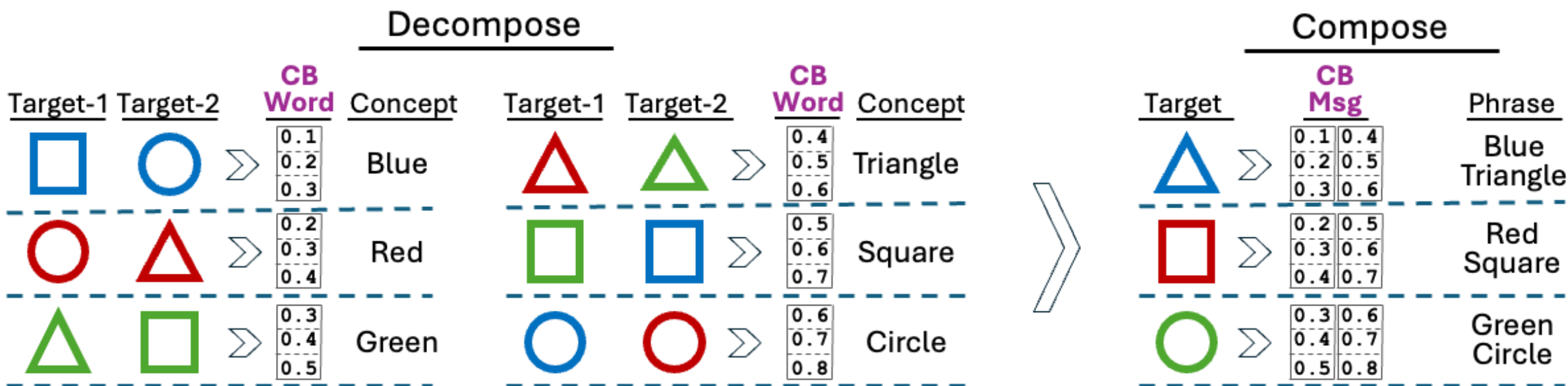# CtD:
Composition through Decomposition
in Emergent Communication

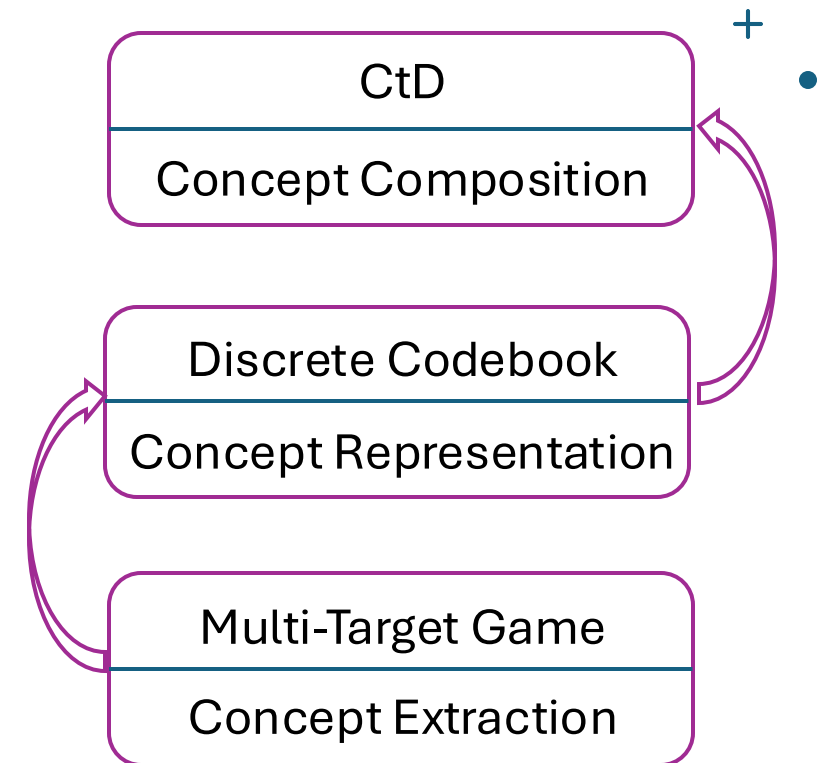**Boaz Carmeli, Ron Meir, Yonatan Belinkov**

The Technion
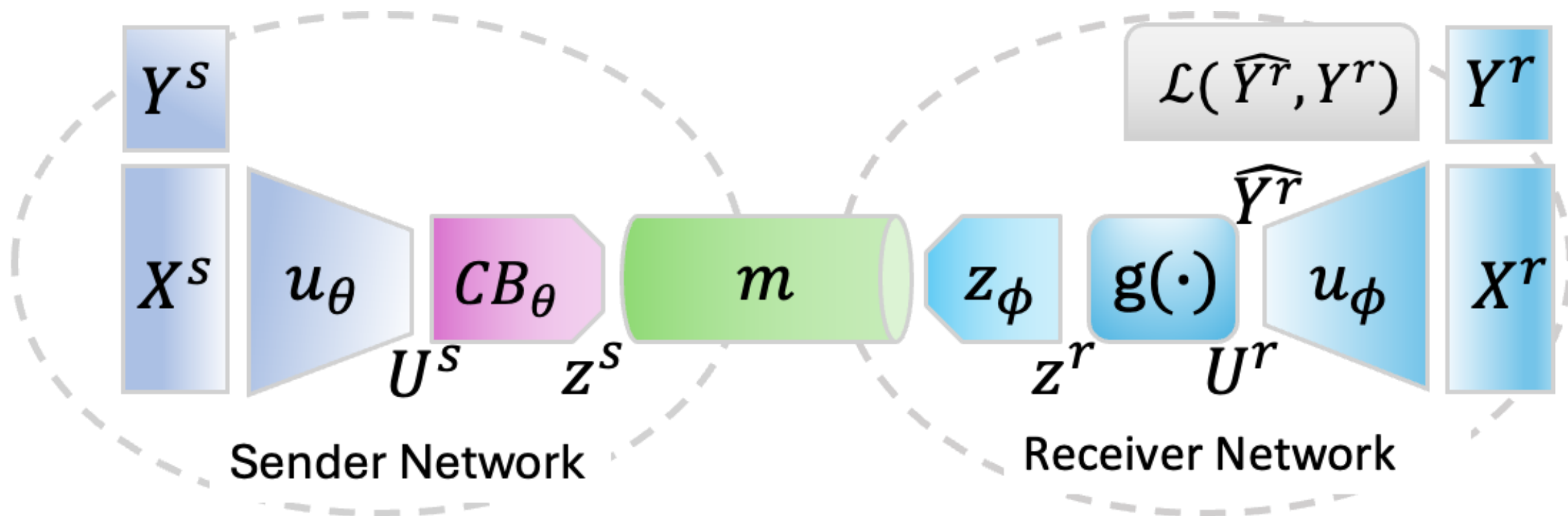**Israel Institute of Technology**

Composition through Decomposition

Contribution

- **Multi-target games:** enable agents to decompose complex objects into basic concepts

- **Discrete codebook**: enables the representation basic concepts in latent space

- **CtD:** leverages codebook-based communication in multi-target coordination games, to compose novel meaning from basic concepts

CtD
Concept Composition

Discrete Codebook
Concept Representation

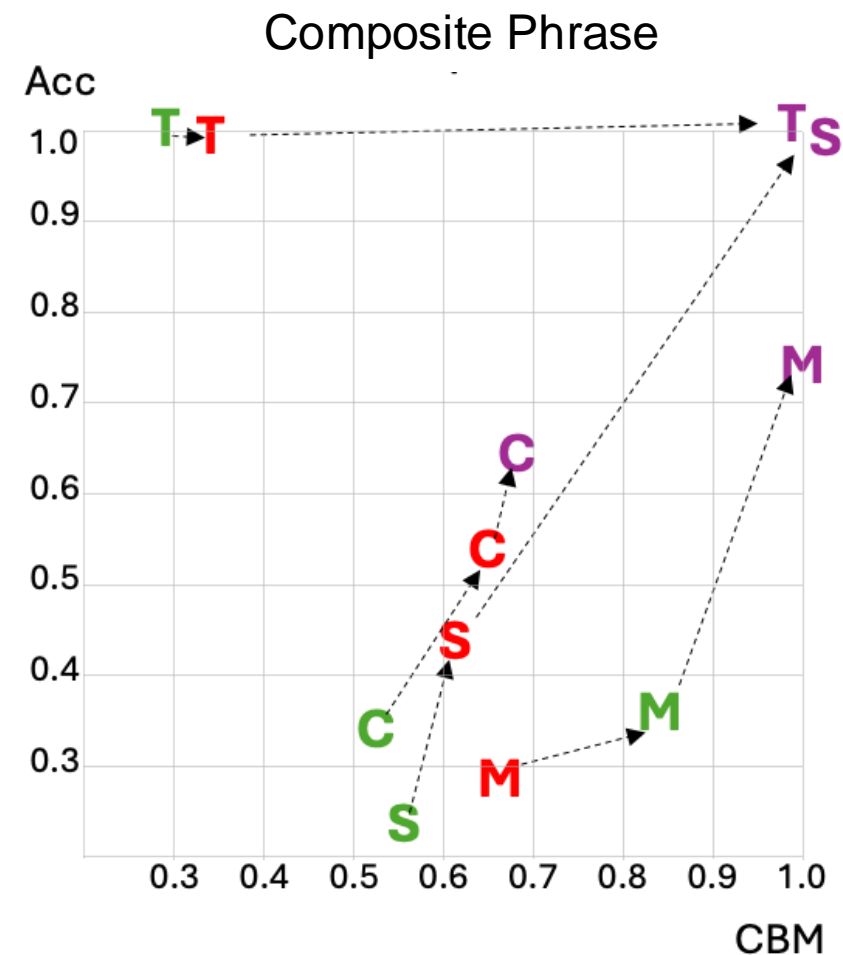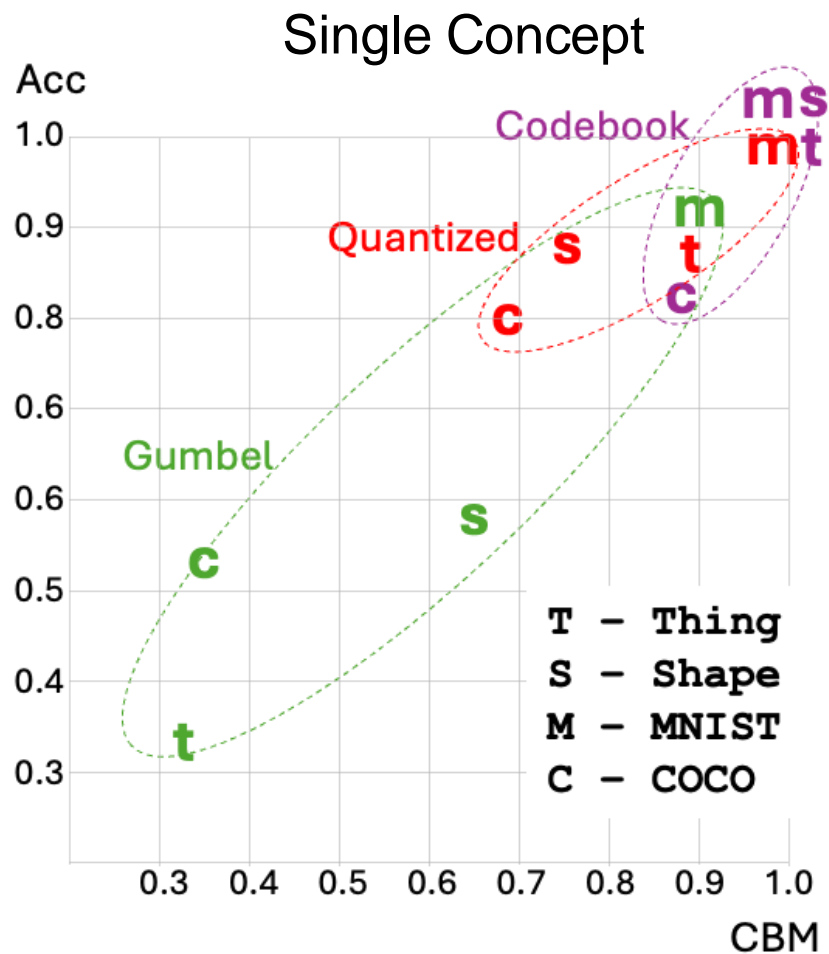| Multi-Target Game |
| --- |
| Concept Extraction |

Using a Codebook in Referential Game

Main Results

Codebook-based communication outperforms both **Gumbel** and **Quantized**-based communication across all configurations
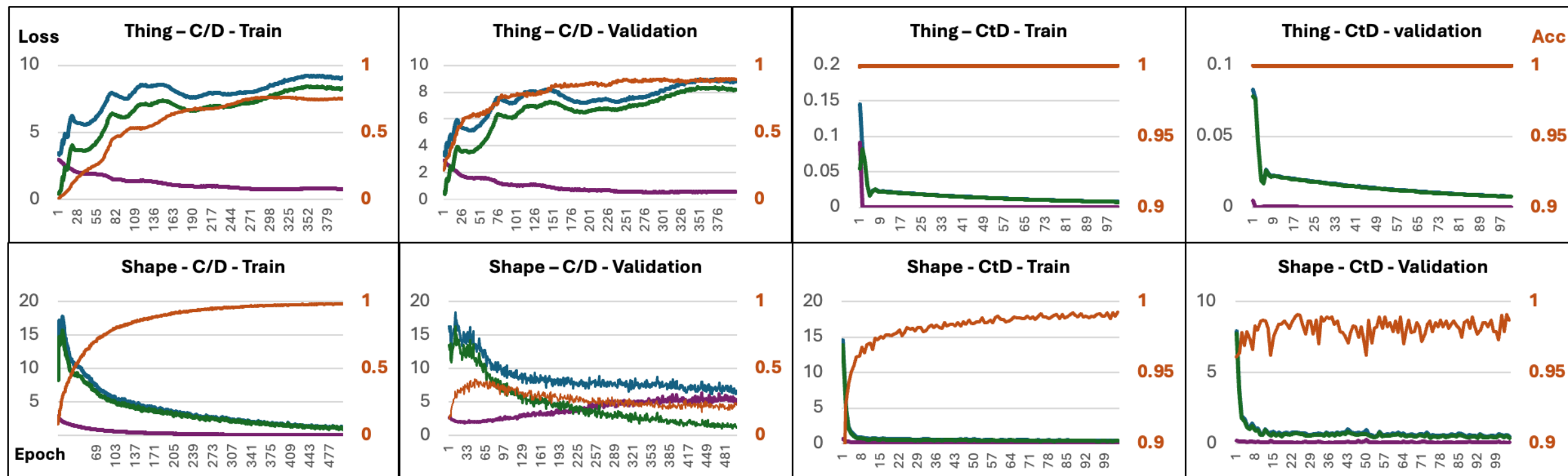

Single Concept

Composite Phrase

T – Thing
S – Shape
M – MNIST
C – COCO

Zero-shot Inference

	THING						SHAPE					
	ACC	AMI	POS	BOS	CI	CBM	ACC	AMI	POS	BOS	CI	CBM
CB-C/D	0.25	0.16	0.01	0.05	0.03	0.25	0.26	0.52	0.05	0.09	0.13	0.47
CB-CtD-ZS	1.00	1.00	0.05	0.98	1.00	1.00	0.81	0.67	0.06	0.84	1.00	1.00
CB-CtD	1.00	1.00	0.05	0.98	1.00	1.00	0.99	0.78	0.07	0.84	1.00	1.00
	MNIST						QRC					
	ACC	AMI	POS	BOS	CI	CBM	ACC	AMI	POS	BOS	CI	CBM
CB-C/D	0.41	0.86	0.08	0.29	0.38	0.58	0.98	0.94	0.00	0.01	0.01	0.17
CB-CtD-ZS	0.89	0.95	0.25	0.26	0.97	0.96	0.48	0.96	0.02	0.37	0.27	0.52
CB-CtD	0.81	0.92	0.09	0.26	0.93	0.95	0.95	0.96	0.00	0.01	0.01	0.17

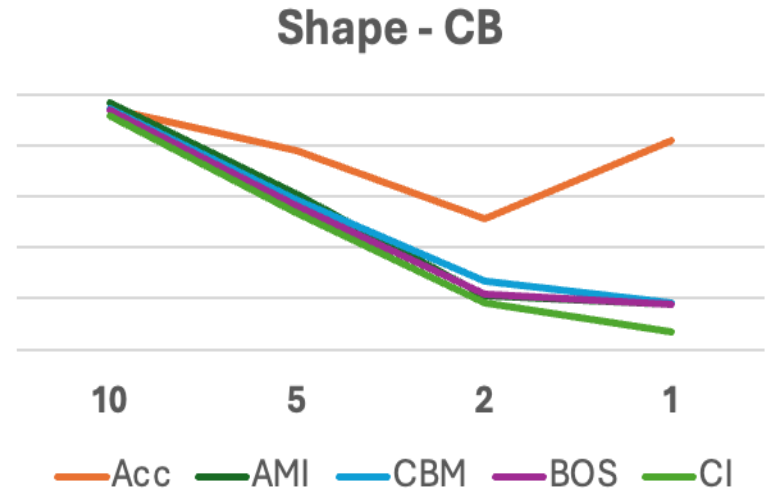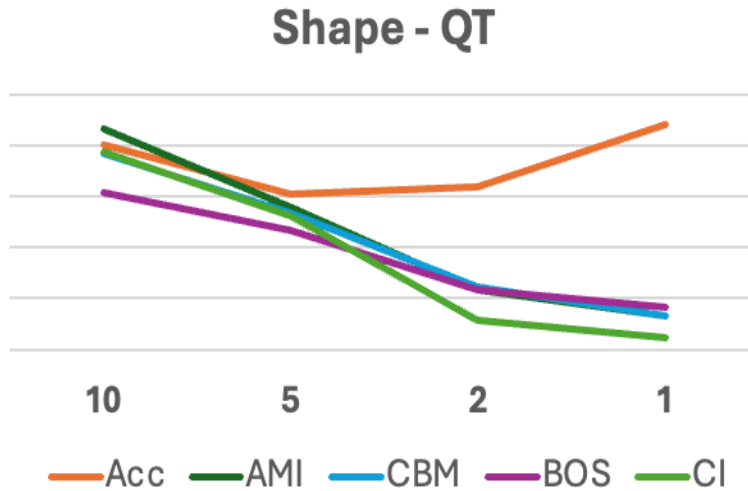With a codebook, CtD can compose known concepts into new meanings without extra training
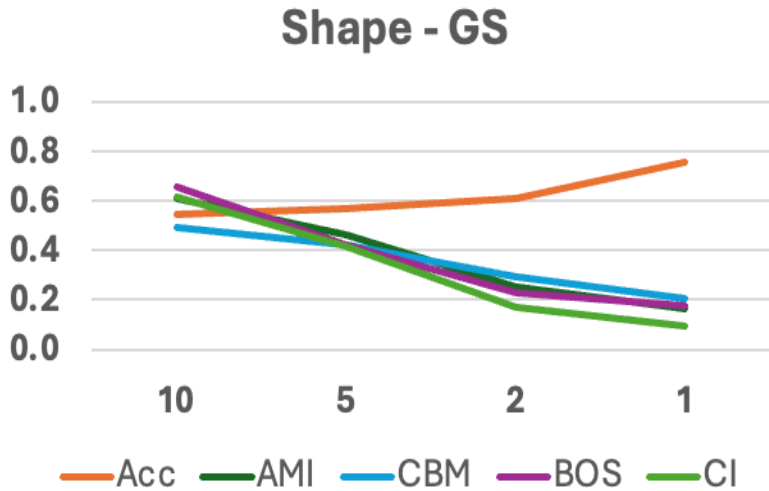
Multi-objective and the need for two-step training

Composition w/o decomposition, results in overfitting with low accuracy (bottom-left) or poor compositionality (top-left), indicated by high communication loss

The Need for Multiple Targets

Reducing the number of targets enhances accuracy but leads to a noticeable decline in all compositionality metrics

To Summarize

Ctd introduces a compositional communication mechanism, allowing agents to build new meanings from basic concepts

Codebook-based communication significantly improves generalization compared to other approaches

Decomposition is key—without it, agents fail to develop a compositional structure