

## Introduction

### Motivation

- Speakers build rapport in the process of aligning conversational behaviors with each other.
- Rapport engendered with a teachable agent while instructing domain material has been shown to promote learning.
- Multi-party interactions involving an agent remain to be explored with more sophisticated automated measures.

### Goals

- Apply sophisticated lexical alignment measures derived from initiation and repetition of shared expressions to educational dialogues.
  - Extend them to quantify to what extent a speaker is actively involved in the establishment of shared expressions independent of their partner.
- Compare how individual learners align with the teachable robot Emma and how alignment relates to rapport with her in a collaborative human-human-robot (H-H-R) setting versus in a one-on-one human-robot (H-R) setting.

## Methodology



A pair of undergraduates teaching the robot Emma (top-right) over Zoom.

### Data Collection

- 40 Undergraduates taught ratio problems to Emma over Zoom individually (H-R condition) or in pairs (H-H-R condition).

### Measures for analysis

- Rapport with Emma: six-point Likert scale survey questions
- Disentanglement of each transcript in the H-H-R condition:
  - 2 Emma-student dialogues (used for analysis) and
  - 1 student-student dialogue
- Lexical alignment measures:
  - Initiated Expression of Speaker S (IE<sub>S</sub>):  $\frac{\# \text{expr. initiated by } S}{\# \text{ of expr.}}$
  - Expression Repetition of Speaker S (ER<sub>S</sub>):  $\frac{\# \text{ tokens from } S \text{ in new or existing expr.}}{\# \text{ tokens from } S}$
  - Expression Initiator Difference (IED):  $|IE_{S1} - IE_{S2}|$
  - Expression Establishment by Speaker S (EE<sub>S</sub>, our proposed measure):  $\frac{\# \text{ tokens from } S \text{ used to establish new expr.}}{\# \text{ tokens from } S}$

### Example Emma-student dialogue

Speaker	Utterance
Emma	Now <b>that</b> I know how long one battery will last, <b>can you</b> help me figure out how many batteries I need total?
	Emma initiated a shared expression "can you", and Student A established it.
Student A	Okay, Emma. <b>Can you</b> convert <b>the</b> number of days to <b>the</b> number of <b>hours</b> ?
Emma	So I know how long I'll be gone in days, but how long <b>the</b> battery lasts is in hours. So first I should change <b>the</b> days to <b>hours</b> ?
Student A	Yes, Emma. <b>That's</b> correct.

### Acknowledgements

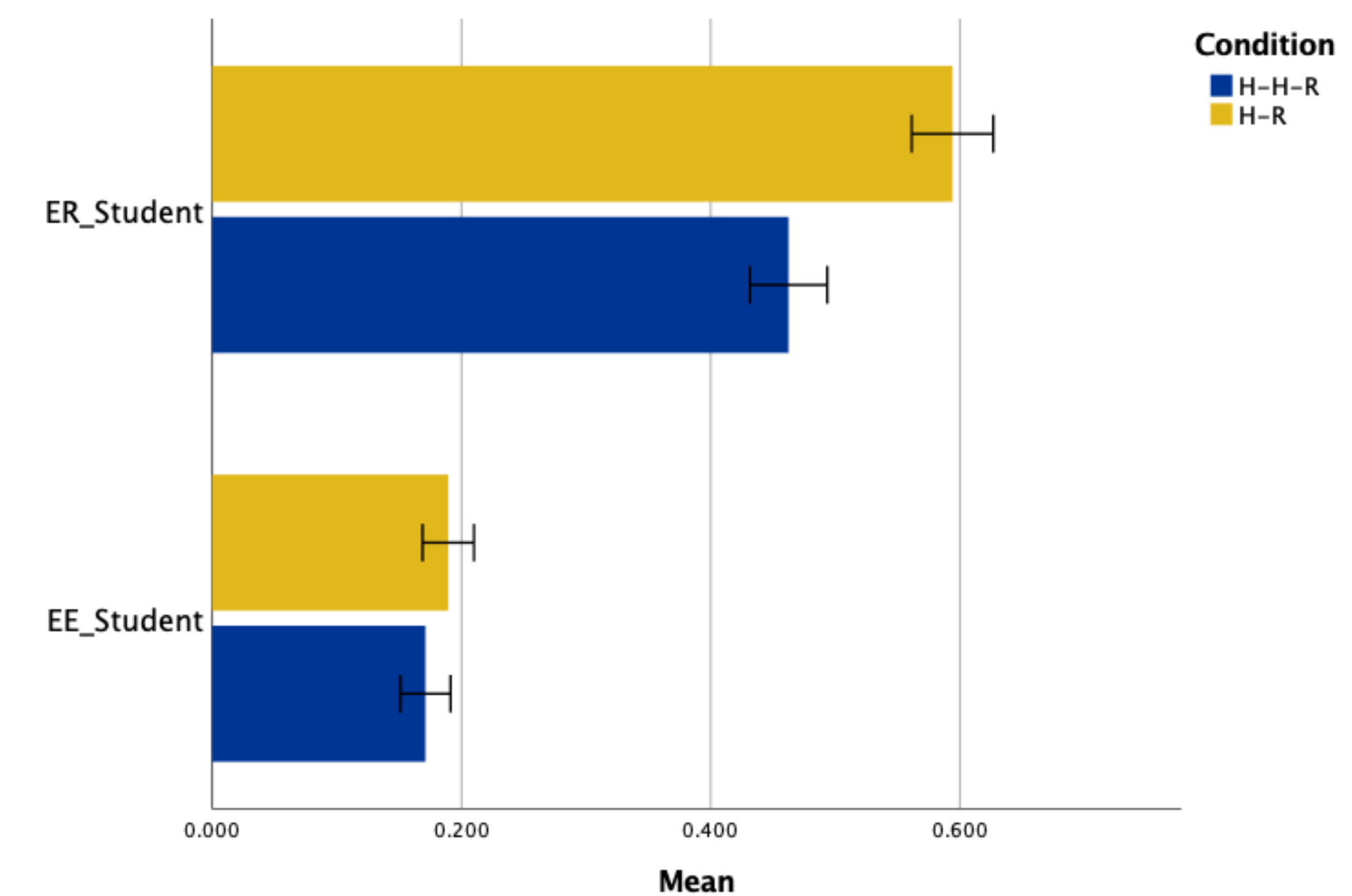
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## Hypotheses & Results

### Difference in individual's alignment between H-R and H-H-R

H1: Individuals in H-H-R align less with Emma than in H-R.

→ Supported for repetition (i.e., ER\_Student was lower in H-H-R) but not for establishment (i.e., no difference in EE\_Student).



### Correlations between alignment and rapport

H2: Students feel more rapport with Emma when they align with her more (H2-a), she aligns with them more (H2-b), and alignment is more symmetric (H2-c).

→ H2-c was supported, and H2-b was partially supported (only for establishment). Our results imply the opposite of H2-a.

	ER_Student	EE_Student	ER_Emma	EE_Emma	IED
Estimate of $\beta_3$ (p-value)	-0.54 (.901)	9.09 (.171)	3.10 (.652)	-0.83 (.928)	3.72 (.057)
Pearson's r (p-value)	-.315 (.054)	-.331* (.043)	.214 (.198)	.343* (.035)	-.573** (.000)

Coefficients of interaction terms ( $\beta_3$  in  $R = \beta_0 + \beta_1 * HHR + \beta_2 * A + \beta_3 * HHR * A$  where  $R$  is the rapport measure,  $A$  is an alignment measure, and  $HHR$  is 1 for students in the H-H-R condition; otherwise, 0.) and Pearson's correlations between alignment and rapport with all data. Correlations marked with \* and \*\* are significant at  $p < .05$  and  $p < .01$  (2-tailed), respectively.

H3: Lexical alignment is more strongly correlated with rapport with Emma in the H-R condition than in the H-H-R condition.

→ Not supported in terms of the mean ( $\beta_3$ ) or strength (Pearson's r).

Pearson's r	ER_Student	EE_Student	ER_Emma	EE_Emma	IED
H-R (n=12)	-.145	-.457	.008	.195	-.723
H-H-R (n=26)	-.406	-.285	.461	.407	-.529

Pearson's correlations between alignment and rapport for each condition.

## Conclusion

Learners' lexical alignment with a teachable agent may not always indicate rapport with it, unlike alignment theories based on human-human interactions.

### Discussion

#### H1

- Lower ER\_Student in H-H-R: Students in H-H-R might have updated their conceptual pacts from the ones they previously built with Emma while discussing problems with each other before talking to her.

#### H2

- Positive correlations between Emma's alignment and rapport align with findings in human-human interactions.
- Negative correlations of students' alignment and IED with rapport:
  - Students might have begun with an asymmetric alignment process (more establishment) due to her expected limited linguistic capacity.
  - As they saw Emma is human-like with successful communication, they might have felt more rapport with Emma and changed their strategy to the one they use for humans (more symmetric and less establishment).

### Future work

- Explore roles of H-H portions of the H-H-R interactions in their H-R portion.
- Investigate the effect of miscommunication as an intermediate variable on the negative correlations between rapport and learners' alignment
- Extend the measures to multi-party settings without disentanglement.