

# Modeling peer effects in interactive learning

Ion Juvina

(with input from Othalia Larue, Peter Crowe, Jarean Carson, & Kevin O'Neill)

Wright State University College of Science and Mathematics Department of Psychology Human Factors & Industrial Organizational Psychology Graduate Program ASTECCA Laboratory



Talk at the 27<sup>th</sup> ACT-R Workshop, July 25<sup>th</sup>, 2020

## Background & Significance

- Much of human learning occurs through <u>interaction</u> with
  - The task environment and
  - Other learners (including experts)
- Knowledge is
  - distributed in the world and in other minds
    - Learners tap into the richness and diversity of knowledge through interaction
  - incomplete, erroneous, or biased
    - Learners must verify, validate, and filter the knowledge gathered from others
- Learning through interaction with other learners
  - has the potential to enhance our collective intelligence (Malone, 2018)
  - Collective intelligence predicts twice as much variance as individual intelligence
    - in complex criteria (Woolley, Chabris, Pentland, Hashmi, & Malone, 2010).

### Evidence from field studies



Active learning pedagogies

- interaction among learners
- learner centeredness
- improved learning outcomes.

Field studies, quasi-experiments:

- not replicable
- confounders

#### Controlled lab experiments:

- establish causality
- understand mechanisms

#### Computational modeling:

- generalization
- theory building
- applications



Ulrich, D. L., Brewer, T. L., Steele-Johnson, D., Juvina, I., Peyton, E. J., & Hammond, C. (2017). Team-Based Learni on Standardized Test Scores and Student Reactions. *Journal on Excellence in College Teaching, 28*(2), 133-165.

### PAL study

• Goal:

understanding the mechanisms and outcomes of peer-assisted learning (PAL)

- Task: Paired-associate learning (PAL)
   Stimuli: 60 word-number pairs
- Key contrasts:
  - Individual vs. peer-assisted learning
  - Passive vs. active learning



### Design: between-subjects conditions

Peer-Assisted Learning (PAL) Individual Interactive Learning

**Passive Learning** 









### Design & procedure

• Within subjects



### School time procedure



### Hypotheses

- Active learning > passive learning
- PAL > Individual interactive learning
  At test (session 7)
- Group performance > Individual performance
- Effort (amount of home time practice) would be lower in PAL condition

Social loafing effect

• Peer inspection data would be informative



### ACT-R model predictions









#### Accuracy by condition and session in school time

In the learning sessions (1 to 6), accuracy in the PAL condition is not higher than in the IL condition.

In the testing session (7), accuracy is lower in the PAL condition than the IL condition.

The group answer is more accurate than the individual answer.

This effect could be a wisdom-of-crowds effect, a knowledge-spillover effect, or both.



#### Learner accuracy as a function of peer accuracy



This is a direct test of a peer effect.

A 1-unit increase in peer accuracy causes a quarterunit (0.25) increase in learner accuracy.

Interacting with a knowledgeable peer in the previous session causes improved accuracy in the current session (and vice versa).

Even though the effect size is small (r = 0.20), this indicates a significant peer

effect.



Maximum peer accuracy in session n-1

#### Taking a peer's answer: frequency and accuracy



Proportion / Accuracy

Taking a peer's answer occurs quite frequently, even though it slightly decreases with learning (black line).

Taking a peer's answer generally occurs when learner accuracy is low, though increasing (red line).

In general, learners become increasingly able to recognize accurate responses in their peers and take them (green line).

However, sometimes they take inaccurate responses

from their peers.





Time in seconds

#### How long participants studied at home in each condition

The participants in the PAL condition did not study less at home. Thus, social loafing cannot explain their poor performance at test.

In fact, they studied significantly MORE than the other conditions.

Home time practice is correlated with test performance, particularly in the PAL condition, r(134) = 0.68.

Why does this effect not lead to better test

#### Looking at correct / incorrect responses



In the PAL condition, learners are exposed to roughly as many incorrect responses as correct ones.

Even though they are able to distinguish the correct ones during the learning sessions, the incorrect associates may persist in memory and interfere with the retrieval of correct responses at test.

Thus, the positive peer effect might be offset by a negative interference effect.



Number of looks

Non-answers by condition

Non-answers predict poor test performance



The number of non–answers vary widely between conditions; it is 5% in the PAL condition and 0.3% in the individual interactive learning condition.

Non-answers predict poor test performance, suggesting that workload explains part of the poorer performance in the PAL condition.

When non-answers are included as a covariate, the difference between the two condition becomes non-significant.

### Summary of findings

- Positive peer effect via
  - Knowledge spillover among peers
  - Increased willingness to practice in the PAL condition
- Negative peer effect via
  - Exposure to incorrect responses
  - Increased workload in the PAL condition



### How to model these effects?

- Minor refinements of the current ACT-R model can handle:
  - Increased workload in the PAL condition
  - Knowledge spillover among peers
  - Exposure to incorrect responses
  - Learning peer trustworthiness
- New mechanism needed to account for:
  - Increased willingness to practice in the PAL condition





### Work in progress

 Series of studies on knowledge-based reasoning and problem solving

Focus on interactive learning

- RAT-PAL study (remote associates test)
  - Search through a large knowledge base (KB)
  - Similarities, occurrences, and co-occurrences
- MAT-PAL study (Miller analogies test)
  - Search through a structured KB (ontology)
  - Understanding / mapping relational structures
  - Finding relationships between relationships



### **Conclusions and implications**

- Clear evidence of positive peer effects
  Via knowledge and motivation channels
- Emergent effects of combining multiple (natural and artificial) minds into super-minds (Malone, 2018)
- PAL may be particularly useful in knowledgeintensive tasks that require large amounts of knowledge and structured KBs (ontologies)
- Evidence of negative peer effects
  - Via error interference and workload
- Modeling challenges that need to be addressed:
  - Forming sophisticated beliefs about others and reasoning on them.



### Contact

• ion.juvina@wright.edu

