How intermittent breaks in interaction improve collective intelligence.

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- **Link to paper**

Overview:
Using the traveling salesman problem, the researchers investigate what role ***time*** will have on the known *positive* and *negative effects* of social influence on problem solving, using a three group, random assignment experiment.

- *Positive effect:* higher average solution quality due to exploitation of existing answers through social learning
- *Negative effect:* lower maximum solution quality due to a reduction in individual exploration for novel answers
- *Treatment Groups:*
    - Control, constant, and intermittent social influence

An additional test was conducted which allowed users to store, and draw upon, their best previous answer.

Key Research Question:
How does social influence—exposure of solvers to each other's behavior or solutions through interacting—affect collective intelligence?

Key Findings:

1) The intermittent social influence group (i.e. the group which had breaks from the social group's influence) "**found the optimum solution frequently (like groups without influence) but had a high mean performance (like groups with constant influence); they learned from each other, while maintaining a high level of exploration.**"
2) Being allowed to store your answer led to substantially less exploration – the effects of which were similar to the constant interaction group.

Summary of Conclusions
Intermittent breaks in interaction improve collective intelligence. Being exposed to diverse answers boosts performance, even if the answers one sees are worse than one's own. To achieve this performance boost within a triad, there is a requirement for both independent exploration (to generate diversity) and interaction (to allow social influence).

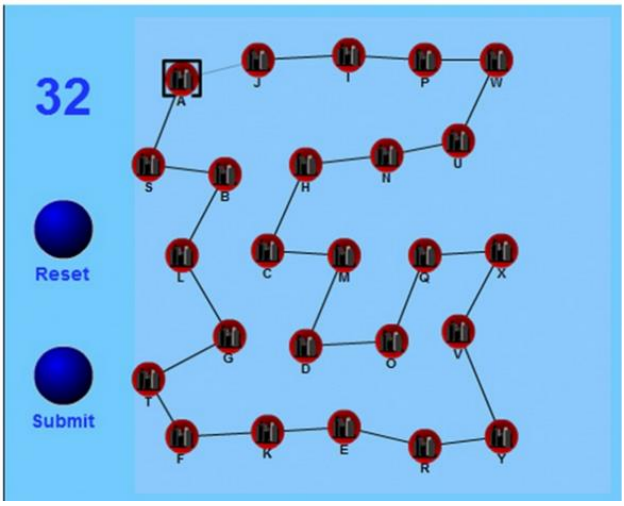
Triads find the optimum more and high performers do even better with intermittent ties, suggesting the presence of beneficial social learning for all participants, not just low performers. Indeed, intermittent social influence may mitigate the dangers inherent in both independent exploration (spending time on poor solutions) and social influence (premature consensus).

Intro/Lit Review:

- Collective intelligence is a disciplinary area of study which has applications in many fields (e.g. understanding groups and team performance, networks, crowds, financial markets, prediction, etc.)
- Past research shows social influence can lead groups to **perform better on simple tasks and problems.**
- For **complex problems**, we know that **integrating diverse ideas together is important**.
- Unfortunately, *social influence can increase the frequency with which people copy other's solutions*.
    - An example of this is brainstorming in the early stages of a project. This has been shown to reduce the number and quality of solutions to complex problems.
- Working in groups, however, has other benefits when tackling a large project or problem.
    - For example, single individuals may simply be unable to handle a large complicated task without coordination – thus, the downside of converging on a suboptimal solution more often may not outweigh the downside of guaranteed failure due to uncoordinated work.

Methods:

- Three groups of three individuals (a.k.a "triads") assigned to three treatment groups (control, constant, and intermittent social influence).
- Asked to perform the traveling salesman problem 17 different times. (see right for example)
- The problem requires that they each *individually* identify the shortest path between different points (displayed visually) without visiting any point twice.
    - The task is designed to be difficult based on the density of the points.
- After each round they are allowed to refine their solution.
- **Treatment: whether they are allowed to learn from the other two individuals in their triad.**
- *Constant ties (CT)*: Allowed to see the solution of their two neighbors after each round
- *Intermittent ties (IT)*: Allowed to see their two neighbors' solutions every third round
- *Control – no ties (NT)*: Never allowed to see their neighbors' solutions



Example Traveling Salesman Problem taken from the original text.

Analysis considers both the **mean solution** and the **best solution** as performance metrics.

Main Results:

*Optimal Solution – finding the best solution **possible***

- CT triads found the optimal solution in 33.3% of trials
- IT triads found the optimum in 48.3% of trials
- NT triads found the optimum in 44.1% of trials
    - Difference between IT and CT was significant after controlling for covariates in a logistic regression

*Best Solution – best solution by the group, **regards** of whether it was the best **possible** solution*

- The best solution found by the IT triads and NT triads was significantly better (shorter) than the best solution found in CT trials
    - log(1+difference from optimal distance) in CT was worse than IT by 0.285, $P < 0.001$ and NT by 0.211, $P < 0.001$
        - **Using the log(1+difference) converts the solution differences into an exponential function. What this does, basically, is devalue differences that are closer to the solution.** If the optimal solution is 25 moves, and person one put 26 moves and person two put 27 moves, this is a difference for person one of 1 move and person two of 2 moves (from the optimal solution). Comparing these two people's differences as they stand, we would say that they differ by one move. However, if we take the log(1 + difference) scores of these values you get .69 (person 1) and 1.09 (person 2), which now gives us a difference between their scores of .49. Thus, participants' scores that are different – but both very close to the solution – matter less than solutions which are drastically different. **This seems like a way to simply make your group mean comparisons more conservative.**
    - IT and NT triads were not statistically different for this measure

Mean Solution – the average solution provided by triad

- IT and CT mean solution were comparable (i.e. not statistically different)
- NT triads was worse than in IT triads
    - log(1+difference from optimal distance) was 0.351 longer, $P < 0.001$
- NT triads was worse than in CT triads
    - 0.449 longer, $P < 0.001$ (same measure as above)

Diversity of Solutions – number of unique solutions

- As expected, more social influence resulted in less diversity of solutions.
    - NT triads: 30.5 unique solutions
    - IT triads: 27.5 unique solutions
    - CT triads: 21.4 unique solutions
        - **While NT triads found more unique solutions than IT triads, they found the optimum solution less frequently than the IT triads.** Thus, the increased diversity of solutions did not really bear better performance.
            - This difference, however, was not statistically significant.

Results Explained:

Improvement between rounds

- The greatest *improvement* that individuals gained was for the IT triad after they were allowed social interaction. However, it appears that this improvement really only occurs after individuals are allowed/forced to explore independently. (E.g. we don't see this for the constant interaction group)
- **Interestingly, this improvement was seen even for the individuals who had provided the best answer so far ("leading" players).**
- That being said, we do see that the "lagging" players gain the most from the "leader" of their triad.

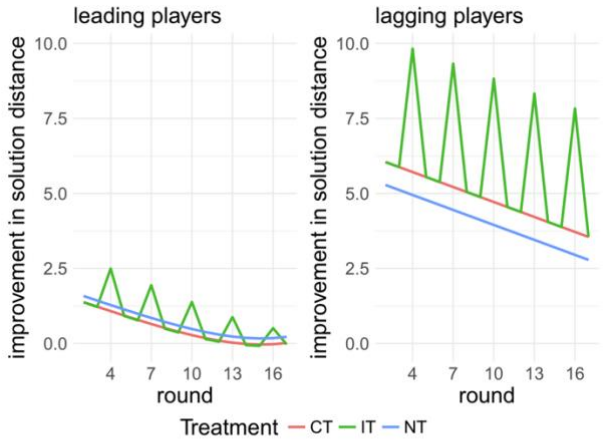


Fig. 2. Fitted values for improvement in solution distance, by round, from model specifications selected and fit by least absolute shrinkage and selection operator (LASSO) regression (31). (*Left*) Improvement for leading players (subject–round pairs in which there was no better solution in the triad in the previous or focal rounds). (*Right*) Improvement for lagging players (subject–round pairs in which there was a superior solution in the triad in the previous round).

Potential to learn from others

- The potential to learn from other members in your triad can be defined as the number of "legs" (moves provided in the TSP answer) that *do not match your other triad members*.
    - E.g. if you and I have the exact same answer, we cannot improve our answers – only when we differ can we see the different answers and (potentially) borrow answers from one another
- They find that the NT triad shares answers the least. However, they have zero potential to learn from one another because they never see each other's answers.
- Comparing the CT and IT triads we see that triad members within the CT triad converge on similar answers in earlier rounds, limiting their ability to:
    a. Explore new solutions, and
    b. Learn from one another
- Furthermore, we can see that in between social influence rounds the IT triads are exploring different options with the solution space.

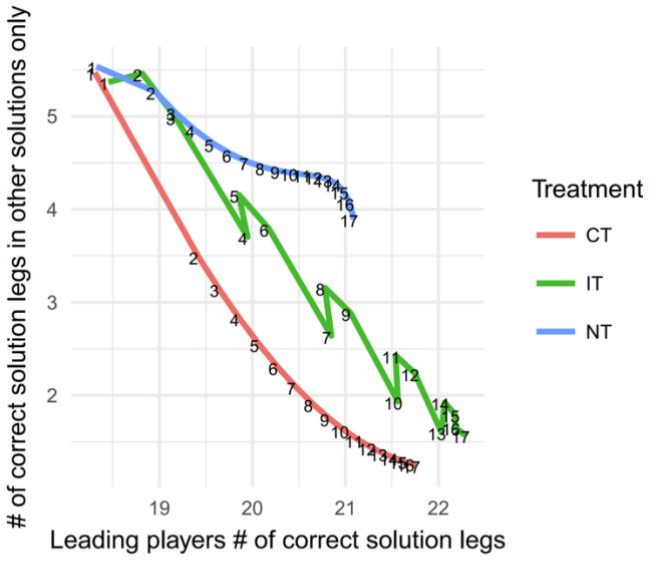


Fig. 3. Possibility of leaders learning from others' solutions by treatment: fitted values (LASSO) for number of correct legs in leading players' solutions versus number of correct legs in other players' solutions that are not present in the focal leading player's solution. Labels indicate round numbers.

Storing Solutions

- Another test was run which allowed the individuals to click a button on the screen and display their best answer so far. Effectively, this option allowed them to store, and then draw on their already existing best answer.
- **Over-all, storing a solver's best solution produced results that were qualitatively similar to social influence**:
    a. Adding storage substantially decreased exploration. Compared to the "without-storage" trials,
        i. CT unique explored 0.748 times the number of solutions
        ii. IT unique explored 0.706 times the number of solutions
        iii. NT unique explored 0.799 times the number of solutions
            - $P < .0001$ for all
- **However, this resulted in an increased mean performance** [log(1+difference from optimal]
    a. CT 0.303 higher, $P = 0.010$
    b. IT 0.271 higher, $P = 0.020$
    c. NT 0.237 higher, $P = 0.009$
- CT, IT, and NT triads found the optimum in 39.1, 39.3, and 38.1% of trials, respectively, representing an increase for CT but decreases for IT and NT.