Studying Peer Effects in Divergent Thinking: Theory and Method

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ABSTRACT

In designing technology that supports user learning, an important first step is to understand how interactions among humans shape mutual learning. Much qualitative research in the realm of peer-assisted learning (PAL) has advanced the theoretical understanding of how social and cognitive factors might influence the success of PAL in educational settings, although fewer studies have examined the effects and mechanisms of PAL experimentally. We review relevant theories on PAL and discuss how the mechanisms of learning, trust, and group heterogeneity can affect peer effects in a divergent thinking context. Thereafter, we propose an experimental study to identify PAL effects and measures of trust and group diversity to be correlated with divergent task learning and performance. Finally, we delineate some potential practical implications of such a study for the Human-Computer Interaction area.

Author Keywords

Peer-assisted learning; divergent thinking; trust; group diversity; dyads.

ACM Classification Keywords

Collaborative and Social Computing; Interaction Design.

General Terms

Human Factors; Experimentation; Theory; Design; Measurement.

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INTRODUCTION

In active learning, interacting with others is a common approach for learners to acquire knowledge and derive inspiration for a variety of tasks. An understanding of how interactions modulate learning has potential to inform complex, collaborative problem-solving and collective intelligence (Leimeister, 2010). Substantial qualitative research has focused on peer-assisted learning (PAL; Topping, 2005; Topping & Ehly, 1998) as a pedagogical strategy for its potential to improve learning outcomes in various educational settings (McMaster & Fuchs, 2016). More recently, research has begun to examine the social and cognitive mechanisms (Loda et al., 2020) of PAL, as well as its costs and benefits when used in different types of cognitive tasks (Crowe et al., 2017). However, relatively little is known from experimental research about the costs and benefits of PAL for tasks in which divergent thinking is required (Torrance, 1970). Moreover, the external validity of constructs like trust in the peer-assisted-learning paradigm is currently unclear given the scarcity of experimental research on this topic. Thus, the purpose of this research was to assess potential advantages and drawbacks of PAL by using an open-ended divergent-thinking task (Olson et al., 2021) and comparing a peer-assisted learning condition with an individual-learning condition, including assessing the roles of cognitive, motivational, and relational mechanisms of interactive learning, such as knowledge spillover, trust, and group diversity.

PEER-ASSISTED LEARNING

Although various definitions for PAL exist in the literature (Ginsburg-Block et al., 2006a; Olaussen et al., 2016), researchers generally agree that PAL, sometimes called peer-learning (PL; Topping, 2005), involves individuals of similar social standing supporting each other on shared learning goals. PAL relies on the assumption that peers can interact in a democratic fashion that empowers the individuals to take ownership of their own learning (Topping & Ehly, 1998). Cooperative learning (CL[1]) is a form of peer learning that does not involve overt peer leadership (Slavin, 1990). CL deemphasizes peer-led interactions (Topping & Ehly, 1998; comparable to peer learning in "ambient" environments in Parr & Townsend, 2002) but stresses the importance of common group goals and individual accountability in situations where group members are interdependent (Johnson & Johnson, 1999; Slavin, 1990). That is, group members are responsible for both their individual performance as well as that of their partners because task completion or success depends on collective effort.

[1] There are subtle differences between cooperative and collaborative learning that we do not address in this paper. Our experimental task implements a form of cooperative learning (i.e., participants work mostly independently and share intermediate products of their work). However, our findings may have wider implications for collaborative learning (i.e., team members working together to achieve common goals).

On the other hand, peer tutoring is a form of structured peer learning that specifies the role-taking of the tutor and the tutee (Topping, 2005). Although differentials such as in experience, knowledge, and age often characterize the tutor-tutee or helper-helped relationship (Forman & Cazdan, 1998), the leadership role can alternate between the members of a tutoring relationship (Fantuzzo et al., 1989), often to the benefit of both the helped and the helper (Henning et al, 2008). Thus, the more recent view on peer tutoring has placed greater emphasis on the benefits of having tutor-tutee pairs that are similar in expertise (Falchikov, 2001; Topping, 2005).

Benefits of Peer Interactions

Peer-assisted learning in its broader scope and various methods of implementation has received substantial scholarly attention regarding its positive effects on educational outcomes, especially when compared to the efficacy of traditional classroom pedagogy. A meta-analysis on PAL in medical education by Guraya and Abdalla (2020) reported pre-post-test effectiveness of PAL (student-led) compared to teacher or faculty-led study groups. PAL schemes benefitted achievement in other academic subjects, including mathematics (Duah et al., 2014), English (Longfellow et al., 2008), and chemistry (Parkinson, 2009).

Additionally, peer-assisted learning formats may support students by relieving stress associated with the presence of instructors and creating a comfortable and safe environment for knowledge sharing and practicing (Weidner & Kopp, 2007). Furthermore, Johnson and Johnson (1989) found that PAL has moderate positive effects on self-esteem, social support, as well as reducing time on task.

Factors Influencing Peer Interactions

PAL does not always guarantee improvement in educational outcomes. Johnson and Johnson (1999) suggested that the successful implementation of cooperative learning requires positive goal interdependence between the group members (i.e., “sink or swim together”), whereas negative goal interdependence fosters within-group competition, and the lack of goal interdependence would deprive group members of individual accountability. Thus, structuring a clear mutual goal is essential for collaborative work (Johnson & Johnson, 1999). Relatedly, Slavin (1983) observed that only cooperative learning methods with group rewards and individual accountability showed positive achievement effects.

Group Diversity

Foot and Howe (1998) argued that some conceptual differences between group members is necessary to foster “operational transacts” (e.g., justification, disagreement, clarification, elaboration; p. 31), which in turn are essential for joint conceptual development or growth in a dialogue. However, grouping students heterogeneously does not guarantee effective collaborative learning. Lan et al. (2007) propounded that a group of students with different levels of skills may require additional scaffolding to overcome challenges associated with group heterogeneity. Correspondingly, Howe et al. (1992) suggested that conceptual differences are beneficial to collaborative learning groups, but only when a shared vocabulary exists between the members.

Importantly, Mannix and Neale (2005) qualified that surface-level social-category differences (e.g., race/ethnicity, gender, age) tend to have negative effects on group functions, whereas fundamental differences in functional background, education, or personality are more conducive to gains in group creativity and problem-solving. In this paradigm, cognitive conflict is a key mediator between heterogeneity and problem-solving as such conflict promotes intellectual development through extensive cognitive restructuring (Parr & Townsend, 2002). Furthermore, task conflicts, which promote knowledge sharing, learning, and creativity, differ from relationship conflicts, which promote divide and undermine trust, hence curtailing knowledge sharing and creativity (Panteli & Sockalingam, 2005).

Group Task Types

Laughlin et al. (2002) observed that groups perform increasingly better than individuals as the demonstrability of the correct solutions increases. According to Laughlin and Ellis (1986), demonstrability entails 1) group consensus on a common conceptual system/vocabulary, 2) sufficient information for the solution, 3) that incorrect members can recognize correct solutions, and 4) that correct members are able and motivated to propose the correct solution. The demonstrability of a task can be mapped onto a continuum of intellective (i.e., with identifiable correct solutions, as in mathematics) versus judgmental tasks (i.e., evaluative, behavioral, aesthetic, and often without correct solutions), with intellective tasks higher in demonstrability. In other words, the superiority of groups over individuals in problem-solving increases with more intellective tasks, which are usually math, object-transfer, vocabulary, or analogical problems (Laughlin et al., 2002).

Importantly, however, Laughlin and colleagues (2002) used an intellective task that encouraged a distributed, complementary group process to solution. A complementary task contrasts with a compensatory task in that group members in the latter format each performs all aspects of the tasks, and the group performance is the mean or median of the independent member performance.

Trust

Multiple studies have documented the relationship between trust and group performance. Mayer et al. (1995) defined trust as the willingness to be vulnerable to another party while expecting that their actions will benefit the trustor. However, whether and how trust exerts a main effect on group performance is not entirely clear. For example, Klimoski and Karol (1976) found a significant main effect of high trust (perception) leading to superior performance in a creative problem-solving task. On the other hand, Dirks (1999) was unable to detect a main effect of trust on group performance, although the researcher identified trust as a moderator between motivation and performance. That is, distrust can result in negative emotional states and loss of focus on achieving a group outcome, whereas trusting in partners helps remove distractors and let the trustor channel his/her energy towards group goals. Yet, Dirks' (1999) argument eluded the important question of why and how individuals decide to trust in a partner in the first place. To that end, Crowe et al., (2017) found that individuals in PAL were able to identify the most accurate peers in their groups and borrow from their responses. Furthermore, Collins and Juvina (2021) posited that trust development is a closed-loop, cyclical process in which trustworthiness is not independent of trust. In other words, the trustworthiness of a person may depend on the trust given to him/her by the trustor. This relationship may represent another indirect pathway by which trust relates to group performance: good performance is related to trustworthiness, which, if detected, should lead to greater trust (i.e., adoption of trustee's answer), reinforcing trustworthiness, and if the trust is warranted, the trustor should benefit from his/her trust in the form of better performance.

DIVERGENT THINKING

Guilford (1967) was the first to use the expression, "divergent production," which refers to the capacity to produce novel solutions to a problem. More broadly, divergent thinking (DT) measures the "capacity to think in many different directions" (Acar & Runco, 2019, para. 5). Guilford (1967) contrasted divergent production from convergent thinking, which is the process of reaching a correct or best solution from multiple already formulated solutions, and suggested three distinct facets of creativity: fluency, originality, and flexibility. Both convergent thinking and divergent thinking contribute to creativity (Kenett et al., 2014; Olson et al., 2021). Although DT is a more obvious component of creativity, whether or not a novel solution is appropriate or useful is another necessary criterion of creativity (Mednick, 1962; Olson et al., 2021).

Current literature favors that two mental processes, associative and executive, undergird the production of novel ideas (Acar & Runco, 2019; Beaty et al., 2014). Whereas the associative theory states that creative individuals have semantic memory structures that allow them to link remote items (Beaty et al., 2014; Kenett et al., 2014; Mednick, 1962), the executive theory posits that creative solutions come from monitoring and inhibiting common associations (Beaty & Silvia, 2012; Beaty et al., 2014; Benedek & Neubauer, 2013). In tandem, these theories highlight the importance of both a flexibly structured knowledge base and top-down control over such knowledge (Beaty et al., 2014). Specifically, large semantic distance values (i.e., greater differences in meaning and usage context between two words, such as "tomato"-"hippo" compared to "cat"-"mouse") is an operationalization of a loosely structured knowledge base, whereas executive switching, the ability to shift between semantic categories (e.g., from one type of object to another, or from objects to philosophies) characterizes the role of executive control, or "controlled attention" (Beaty et al., 2014; Nusbaum & Silvia, 2011).

Divergent Thinking Tasks

The most common measure of divergent thinking is the Alternate Uses Tasks (AUT) (Gilhooly et al., 2007; Olson et al., 2021), which asks participants to generate novel uses of everyday objects (e.g., a paper clip) and is typically scored on the dimensions of fluency, originality, and flexibility. Despite its popularity, the AUT remains a relatively labor-intensive task to score. For example, to prevent rater subjectivity from biasing the results, the AUT typically requires multiple raters (Silvia et al., 2008). Furthermore, the open-endedness of the AUT means that responses are sample dependent (Olson et al, 2021; Silvia et al., 2008), making the comparison of originality (which depends on the frequency of an alternate use in the sample) non-absolute. Even with the use of computer scoring such as Latent Semantic Analysis (LSA) (Acar & Runco, 2019), such scoring still needs to account for artefacts such as fluency contamination (i.e., high fluency (response quantity) inflates the number of original responses) (Forthmann et al., 2018).

In light of these challenges, Olson et al. (2021) developed the Divergent Association Task (DAT), which asks participants to generate 10 words that are as unrelated in meaning and usage as possible. The DAT depends on the calculation of semantic distances between the generated words, a method used in the LSA scoring of the AUT (Acar & Runco, 2015; Acar & Runco, 2019). However, whereas fluency can inflate AUT originality scores by increasing the number of words (and thus greater likelihood of semantically distant words), the DAT limits the number of responses to 10, thereby curtailing the fluency contamination without sacrificing the open-endedness of the task (Olson et al., 2021). Moreover, the use of a common corpus and a scoring algorithm (i.e., semantic distance) allows comparison of DT scores across samples. Most importantly, the DAT demonstrates strong convergent validity with the three dimensions of the AUT, with correlations between DAT and AUT at least as strong as those among AUT dimensions themselves, although appropriateness is an aspect that the DAT cannot measure reliably (Olson et al., 2021).

Learnability of Divergent Thinking

Some research suggests that creative thinking is not an immutable trait but a learned skill. Perhaps the most prominent piece of evidence comes from research on the serial order effect, which is the tendency for the originality of ideas to increase with time during consecutive idea generation (Beaty & Silvia, 2012; Mednick, 1962; Milgram & Rabkin, 1980). According to the associative model of DT (Mednick, 1962), this order effect occurs because people reach novel responses, which are farther to a stimulus in a semantic network, only after reaching common responses, which are closer to the stimulus. In other words, this phenomenon involves the spreading of activation to increasingly remote ideas. On the other hand, Beaty and Silvia (2012) argued that executive processes such as strategic retrieval and knowledge manipulation are more likely to have occurred. They observed that the serial order effect diminished with individuals' greater fluid intelligence, which can contribute to the ability to inhibit common associations even at the beginning of a DT task. In the same vein, Gilhooly et al. (2007) found that, in AUT, readily retrieved instances of alternate uses preceded more effortful executive processes such as inhibition and switching. Moreover, Olson et al. (2021) submitted that the DAT may be susceptible to strategizing, which is an executive function. Taken together, these findings suggest that learning of a DT task (not DT per se) is possible, by engaging more intelligent and effective executive control strategies as time increases and/or task progresses.

PROPOSED STUDY

The literature provides evidence that peer-assisted learning is effective in a variety of learning environments (e.g., Ginsburg-Block et al., 2006a; Durak, 2022), but whether and how PAL effects translate into the creative problem-solving context requires further research (e.g., Mannix & Neal, 2005).

Overview

To study the effects and mechanisms of PAL, we designed a dyadic cooperative learning scenario in which participants in each dyad will complete a version of the DAT multiple times. Participants will be randomly assigned to two experimental conditions, Individual Learning (IL) and Peer-Assisted Learning (PAL), the main difference between which is that PAL participants receive input from their peers in their respective dyads, whereas the IL participants work independently.

Variables

As delineated in the literature review, peer effects, group diversity, trust, and the learnability of divergent thinking are important issues which need to be addressed. The *overall peer effect* on DAT can be measured by contrasting the DAT scores between IL and PAL. Whether *group/dyad diversity* is related to performance can be calculated with the semantic distances of words generated by each pair of participants in a dyad. *Trust* can be operationalized as the frequency of adopting peer input, while peers' performance can be a proxy for their *trustworthiness*. Finally, by having participants perform multiple rounds of the DAT, we can observe any *learning* or serial order effect in the form of increased DAT scores.

Hypotheses

General Peer Effect

Participants in the peer-assisted learning (PAL) condition will obtain different average DAT scores, higher or lower, than participants in the individual learning (IL) condition. This non-directional hypothesis reflects the mixed findings from the literature on peer effects (i.e., both benefits and costs have been reported), as reviewed above.

Diversity

In PAL, the semantic distance between the two sets of peer input in each dyad would be positively correlated with the dyad-average DAT scores. In other words, the more conceptually diverse a dyad, the higher its performance.

Trust

1. In the PAL condition, the trustees' DAT scores would be positively correlated with the trustees' perceived trustworthiness (frequency of own responses adopted by partners)
2. In the PAL condition, the trustors' trust in their partners (frequency of adopting partner's responses) would be positively correlated with the trustors' DAT scores.
3. In the PAL condition, per-dyad trust behaviors (frequency of adopting partners' responses) would be positively correlated with the dyad-average DAT scores.

Learning

DAT scores would differ across the repeated attempts (rounds) of the task. Specifically, DAT scores would be higher in later rounds compared to those in the earlier rounds.

METHOD

Task Description

The task for this study was derived from the Divergent Association Task (DAT) developed by Olson et al. (2020), which provides a reliable measure of divergent thinking with a relatively objective scoring scheme free of fluency contamination. Henceforth, we refer to the DAT adapted for this study of divergent thinking in PAL settings as the DAT-PAL task.

Task Objective

The goal of the participants in the DAT-PAL task is to generate words that are each as semantically distant or different as possible from one another. For example, if "drive" is the first word a participant thinks of, she would then want to think of a second word that is as different as possible from "drive" in all its possible meanings. "Car" or "motivation" would generate a low semantic distance score with "drive," whereas a word like "tomato" or "hippopotamus" would generate a higher score with "drive." In this sense, semantic distance measures the unrelatedness of two words in both their definitions and their contexts of use. Importantly, unrelated words are usually not antonyms, which despite their oppositeness can be commonly related in the same context. For a third word in the series, the participant would want to think of a word that is unrelated to both "drive" and "tomato," and this process is reiterated until the participant generates ten of such unrelated words. From the ten words, the algorithm computes the semantic distance scores for all possible word pairs (10 combinations of 2 = 45 pairs), and the DAT score for the ten words is an average score for the 45 pair scores. Figure 1 provides an illustration of how a set of ten words is scored.

Overall Task Flow

In DAT-PAL, each participant will perform the DAT (i.e., generating ten unrelated words) ten times. Each instance of the DAT, now referred to as a "round," will generate a DAT score based on the average semantic distance among the ten words, and a total of ten DAT scores would be generated when the participant completed the experiment.

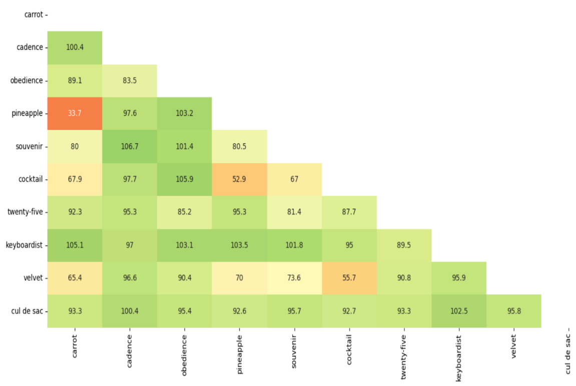

Figure 1. A matrix of 45 noun pairs generated from 10 words. Commonly associated words such as "pineapple" and "carrot" or "pineapple" and "cocktail" led to lower semantic distance scores, whereas "cocktail" and "obedience" led to a higher score of 105.9 because of their unrelatedness. The average score (i.e., DAT score) of this wordlist is 88.89. To complete the experiment, each participant will generate ten of such ten-word lists.

Within-Round Task Flow

Please refer to Figure 2. The goal of each round is to generate a list of ten unrelated words (nouns). Within each round, the task of generating each of the ten words is scaffolded into three steps: 1) generate a "First Word," 2) generate/review a "Second Word," and 3) decide the "Final Word." The first and Second Words provide opportunities for the participant to brainstorm the potential candidates for each of the ten words that would be eventually scored. For example, any of the first two words ("carrot", "storm") in the first row can be the candidates for the "Final Word" of this row. The participant can also select a word different from the first two words as a Final Word. Eventually, only the ten "Final Words" will be scored per round.

The purpose of this scaffolding is to ensure the equivalence between the IL and PAL conditions and to generate opportunities for interaction among participants. In the IL condition, the participant generates all 30 words (with overlaps) for each round (i.e., all first, second, and final words). In the PAL condition, participants work in pairs, or dyads, and each participant in a dyad would only need to generate a First Word and a Final Word for each row, totaling to 20 self-generated words (with overlaps). After a Participant A generated a First Word, the software would display this First Word on the Second Word textbox of the A's partner, B, and the B's First Word would likewise be reciprocated onto the textbox of A's Second Word. In essence, participants in the PAL condition view their partners' First Word instead of generating a Second Word. As in the IL condition, PAL participants can decide whether they would use their partners' words as their own Final Words. Hence, the Final Words could also be scored individually in each dyad as in IL. Additionally, we will include a group score to add incentive for participants in PAL to provide useful input for their partners.

This within-round scaffolding for word generation provided symmetry in task flow between the two conditions, thereby making the difference between generating a Second Word and viewing a Second Word the only differentiation between IL and PAL. Correspondingly, however, only DAT scores could be used to analyze the differences in learning effects between the two conditions since implicit in the PAL effect is the shorter individual processing/response time.

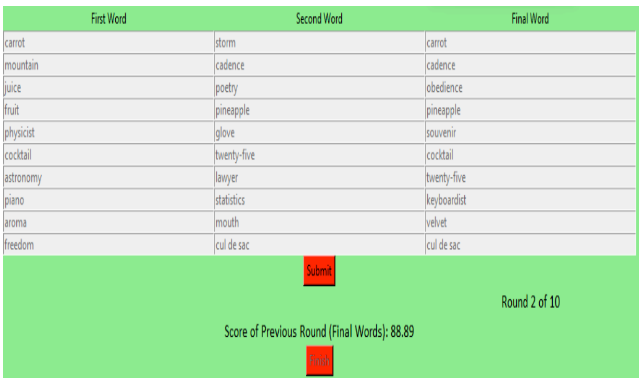

Figure 2. The interface of a single DAT-PAL round (IL condition). The participant progressed across each row before moving onto the next (e.g., "carrot" -> "storm" -> "carrot," then "mountain" -> "cadence" -> "cadence"). Both the "First Word" and the "Second Word" can be used as "Final Word," (e.g., row 1 "carrot") which can also be a word not listed in the first two (e.g., row 3 "obedience"). A word brainstormed for a previous

Final Word, if not already selected, can be the candidate of another Final Word later in the round (e.g., "twenty-five").

Design

The DAT-PAL study consisted of an individual learning (IL) condition and a peer-assisted learning (PAL) condition, which together represent the two levels of the independent variable in a two-sample between-groups design. Participants in the IL condition will complete the DAT individually whereas participants in the PAL condition will be grouped in dyads in which they can share their responses to the DAT with each other. The PAL condition represents group/cooperative learning (e.g., Slavin, 1990). Both the IL and PAL groups will perform the DAT through a computer software interface, which will be visually and functionally identical for both groups except that the PAL software will mediate the exchange of task responses between the dyad partners.

This study will involve a randomized block factorial design (RBF-2.10). The blocking variable will be cognitive ability (CA), by which we would match two participants of similar CA into one block, and one participant would be randomly assigned to IL, with the other to PAL. The rationale for participant matching is that fluid intelligence can influence creative task performance (Beaty & Silvia, 2012) and this is an effective way to control for this variable. For the across-rounds learning effects, each participant would be his/her own block, performing ten repeated measures of the DAT-PAL.

To examine the variables of group diversity, trust, and trustworthiness, we will perform the following regression analyses. We will regress dyad-average DAT scores onto peer-input semantic distance, trustees' trustworthiness onto trustees' DAT scores, trustors' DAT scores onto their trust of their partners, and dyad-average DAT scores onto per-dyad trust behaviors.

Measures

DAT Scores represent the operationalized dependent variable of performance in the divergent thinking (DT) task. A *round-wise DAT score* is computed per round (i.e., ten-words). An *experiment-wise DAT score* is averaged across the ten rounds per individual. In the PAL condition, both round-wise and experiment-wise DAT scores can be averaged to obtain round-wise dyad-average and experiment-wise dyad-average scores.

Trust (of Trustors, PAL condition) is operationalized as the number of First Words a participant (trustor) adopted from her partner. Each dyad would have two individual measures of trust per round. Trust will be averaged into experiment-wise (i.e., across-round) means per individual, and these averages are the predictor for the trustors' experiment-wise DAT scores.

Trustworthiness (of Trustees, PAL condition) is operationalized as the number of First Words adopted by a participant's (trustee's) partner. Each dyad would have two individual measures of trustworthiness per round. Trustworthiness will be averaged into experiment-wise (i.e., across-round) means per individual, and these averages are the outcome measure for individual experiment-wise DAT scores.

Semantic Distance is the basic unit of the level of relatedness between two words. Although various measures of semantic distance are available (e.g., Landauer et al., 1997), we follow the semantic distance measure used in the DAT (Olson et al., 2020) called GloVe (Pennington et al., 2014), which was based on the Common Crawl corpus. As described in Task Description, the DAT used semantic distance to calculate DAT scores. The semantic distance measure (SemDis) referred hereto is calculated by juxtaposing Participant A's First Words with Participant B's First Words (in a single round) and taking the average of

∑[SemDis(FirstWordA1,FirstWordB1),
SemDis(FirstWordA1,FirstWordB2)…
SemDis(FirstWordA1,FirstWordB10)…
SemDis(FirstWordA10, FirstWordB10)].

Unlike DAT scores, this semantic distance measure does not include the semantic distances among the First Words by the same participant but instead cross-computed the semantic distance between two sets of First Words, per round. This round-wise, dyad-average SemDis will be used as proxy for cognitive diversity to predict round-wise, dyad-average DAT scores.

SOFTWARE

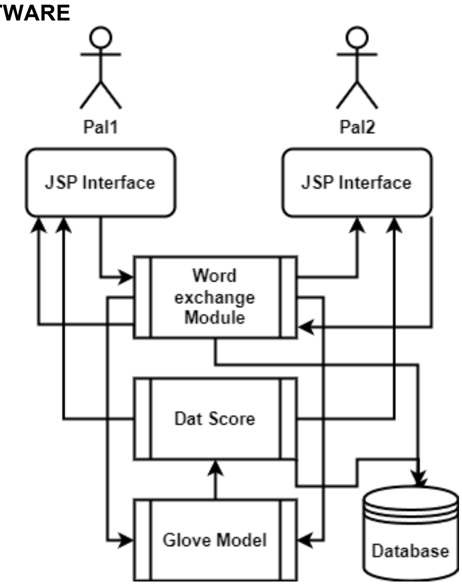

Figure 3. Overall system design

Figure 3 presents the overall system design, which starts from the words provided by the two participants referred to as "pals" in the figure. The word exchange module updates the pal's interfaces with the words entered by each other. For each word sent by one of the pals we make an input in the database to save the progress at each step. The DAT score is also saved in the database and computed for the input words based on the glove model, which is preloaded in memory together with its own dictionary. Using a dictionary for most common nouns is useful because loading a whole glove model takes time and uses plenty of memory.

The data interchange is done using WebSocket technology. When the first user hits the DatPal section, we start a waiting list, which is always completed with the second user who hits the DatPal button. After that, we define web sockets for each set of words interchange and save the last words in the database at each step.

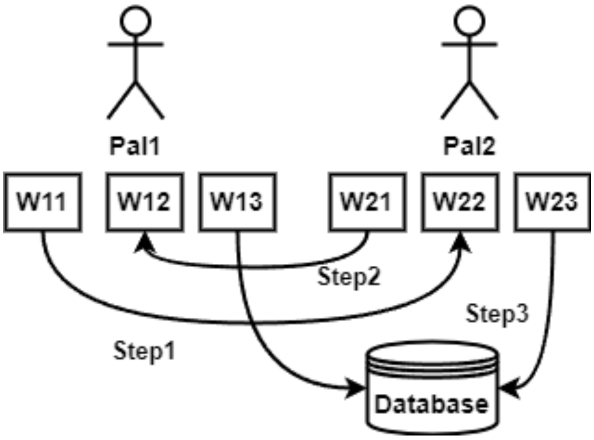

Figure 4. Pal words interchange

The word interchange between the two pals is shown in Figure 4. The first step when the pals are connected is when Pal 1 enters the first word (w11), which opens a web socket and sends the word to the second pal as his second word (w22). After Pal 2 sends his word (w21), we go to step 2, where Pal1 gets it (w12), and both can see the other's word. The last step (3) is completed after each pal enters their word, and these words (w13 and w23) are saved directly in the database along with their timestamp.

The application development is done in Java using JSP technology along with JavaScript for WebSockets. It uses a Tomcat as the application server and a MySQL server to store the database.

CONCLUSION AND IMPLICATIONS

We have made a case here for the need to study the effect of peer interaction on learning and performance in a divergent thinking task. Peer interaction has the potential to generate a variety of viewpoints and creative solutions to novel problems. The insights gained from this research can inform the design of collaborative learning and problem solving tools.

We envision this research will have important implications for the field of human-computer interaction (HCI). Insights from peer-assisted learning can inform the design of systems to facilitate cooperative work between humans or between humans and machines. For example, this research can guide the creation of cooperative AI agents that can work harmoniously with human users, facilitating cooperative problem-solving and learning experiences.

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REFERENCES

1. Acar, S., & Runco, M. A. (2015). Thinking in multiple directions: Hyperspace categories in divergent thinking. *Psychology of Aesthetics, Creativity, and the Arts*, *9*(1), 41–53.
2. Acar, S., & Runco, M. A. (2019). Divergent thinking: New methods, recent research, and extended theory. *Psychology of Aesthetics, Creativity, and the Arts*, *13*(2), 153-158.
3. Beaty, R. E., & Silvia, P. J. (2012). Why do ideas get more creative across time? An executive interpretation of the serial order effect in divergent thinking tasks. *Psychology of Aesthetics, Creativity, and the Arts*, *6*(4), 309–319.
4. Beaty, R. E., Silvia, P. J., Nusbaum, E. C., Jauk, E., & Benedek, M. (2014). The roles of associative and executive processes in creative cognition. *Memory & Cognition*, *42*(7), 1186-1197.
5. Benedek, M., & Neubauer, A. C. (2013). Revisiting Mednick's model on creativity□related differences in associative hierarchies. Evidence for a common path to uncommon thought. *The Journal of Creative Behavior*, *47*(4), 273-289.
6. Collins, M. G., & Juvina, I. (2021). Trust miscalibration is sometimes necessary: An empirical study and a computational model. *Frontiers in Psychology*, *12*, 690089.
7. Crowe, P., Collins, M., Larue, O., Green, R., Hough, A., & Juvina, I. (2017). Examining the role of trust in peer-assisted learning. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *61*(1), 165–169.
8. Dirks, K. T. (1999). The effects of interpersonal trust on work group performance. *Journal of Applied Psychology*, *84*(3), 445-455.
9. Duah, F., Croft, T., & Inglis, M. (2014). Can peer assisted learning be effective in undergraduate mathematics? *International Journal of Mathematical Education in Science and Technology*, *45*(4), 552-565.

10. Falchikov, N. (2001). *Learning together: Peer tutoring in higher education*. Psychology Press.
11. Fantuzzo, J. W., Riggio, R. E., Connelly, S., & Dimeff, L. A. (1989). Effects of reciprocal peer tutoring on academic achievement and psychological adjustment: A component analysis. *Journal of Educational Psychology*, *81*(2), 173–177.
12. Foot, H., & Howe, C. (1998). The psychoeducational basis of peer-assisted learning. In K. Topping & S. Ehly (Eds.), *Peer-assisted learning* (pp. 27-43). Routledge.
13. Forman, E., & Cazdan, C. (1998). Exploring Vygotskian perspectives in education. In D. Faulkner, K. Littleton, & M. Woodhead (Eds.), *Learning relationships in the classroom* (pp. 189-206). Routledge.
14. Forthmann, B., Oyebade, O., Ojo, A., Günther, F., & Holling, H. (2019). Application of latent semantic analysis to divergent thinking is biased by elaboration. *The Journal of Creative Behavior*, *53*(4), 559-575.
15. Gilhooly, K. J., Fioratou, E., Anthony, S. H., & Wynn, V. (2007). Divergent thinking: Strategies and executive involvement in generating novel uses for familiar objects. *British Journal of Psychology*, *98*(4), 611-625.
16. Ginsburg-Block, M., Rohrbeck, C., Fantuzzo, J., & Lavigne, N. C. (2006a). Peer-Assisted Learning Strategies. In G. G. Bear & K. M. Minke (Eds.), *Children's needs III: Development, prevention, and intervention* (pp. 631–645). National Association of School Psychologists.
17. Guilford, J.P. (1967). *The nature of human intelligence*. McGraw-Hill.
18. Guraya, S. Y., & Abdalla, M. E. (2020). Determining the effectiveness of peer-assisted learning in medical education: a systematic review and meta-analysis. *Journal of Taibah University Medical Sciences*, *15*(3), 177-184.
19. Henning, J. M., Weidner, T. G., & Marty, M. C. (2008). Peer assisted learning in clinical education: Literature review. *Athletic Training Education Journal*, *3*(3), 84-90.
20. Howe, C. J., Tolmie, A., Anderson, A., & Mackenzie, M. (1992). Conceptual knowledge in physics: The role of group interaction in computer-supported teaching. *Learning and Instruction*, *2*(3), 161-183.
21. Johnson, D. W., & Johnson, R. T. (1989). *Cooperation and competition: Theory and research*. Interaction Book Company.
22. Johnson, D. W., & Johnson, R. T. (1999). Making cooperative learning work. *Theory into Practice*, *38*(2), 67-73.
23. Kenett, Y. N., Anaki, D., & Faust, M. (2014). Investigating the structure of semantic networks in low and high creative persons. *Frontiers in Human Neuroscience*, *8*, Article 407.
24. Klimoski, R. J., & Karol, B. L. (1976). The impact of trust on creative problem solving groups. *Journal of Applied Psychology*, *61*(5), 630-633.
25. Lan, Y. J., Sung, Y. T., & Chang, K. E. (2007). A mobile-device-supported peer-assisted learning system for collaborative early EFL reading. *Language Learning & Technology*, *11*(3), 130-151.
26. Laughlin, P. R., Bonner, B. L., & Miner, A. G. (2002). Groups perform better than the best individuals on Letters-to-Numbers problems. *Organizational Behavior and Human Decision Processes*, *88*(2), 605-620.
27. Laughlin, P. R., & Ellis, A. L. (1986). Demonstrability and social combination processes on mathematical intellective tasks. *Journal of Experimental Social Psychology*, *22*(3), 177-189.
28. Leimeister, J. M. (2010). Collective intelligence. *Business & Information Systems Engineering*, *2*, 245-248.
29. Loda, T., Erschens, R., Nikendei, C., Zipfel, S., & Herrmann-Werner, A. (2020). Qualitative analysis of cognitive and social congruence in peer-assisted learning–The perspectives of medical students, student tutors and lecturers. *Medical Education Online*, *25*(1), 1801306.
30. Longfellow, E., May, S., Burke, L., & Marks-Maran, D. (2008). 'They had a way of helping that actually helped': A case study of a peer-assisted learning scheme. *Teaching in Higher Education*, *13*(1), 93-105.
31. Mannix, E., & Neale, M. A. (2005). What Differences Make a Difference? The Promise and Reality of Diverse Teams in Organizations. *Psychological Science in the Public Interest*, *6*(2), 31-55.
32. Mayer, R. C., Davis, J. H., & Schoorman, F. D. (1995). An integrative model of organizational trust. *The Academy of Management Review*, *20*(3), 709-734.
33. Mednick, S. (1962). The associative basis of the creative process. *Psychological Review*, *69*(3), 220-232.
34. McMaster, K., Fuchs, D. (2016). Classwide Intervention Using Peer-Assisted Learning Strategies. In S. Jimerson, M. Burns, & A. VanDerHeyden (Eds.), *Handbook of response to intervention* (pp. 253-268). Springer.
35. Milgram, R. M., & Rabkin, L. (1980). Developmental test of Mednick's associative hierarchies of original thinking. *Developmental Psychology*, *16*(2), 157-158.
36. Nusbaum, E. C., & Silvia, P. J. (2011). Are intelligence and creativity really so different? Fluid intelligence, executive processes, and strategy use in divergent thinking. *Intelligence*, *39*(1), 36-45.

37. Olaussen, A., Reddy, P., Irvine, S., & Williams, B. (2016). Peer-assisted learning: time for nomenclature clarification. *Medical Education Online*, *21*(1), 30974.
38. Olson, J. A., Nahas, J., Chmoulevitch, D., Cropper, S. J., & Webb, M. E. (2021). Naming unrelated words predicts creativity. *Proceedings of the National Academy of Sciences*, *118*(25), e2022340118.
39. Panteli, N., & Sockalingam, S. (2005). Trust and conflict within virtual inter-organizational alliances: A framework for facilitating knowledge sharing. *Decision Support Systems*, *39*(4), 599-617.
40. Parkinson, M. (2009). The effect of peer assisted learning support (PALS) on performance in mathematics and chemistry. *Innovations in Education and Teaching International*, *46*(4), 381-392.
41. Parr, J. M., & Townsend, M. A. (2002). Environments, processes, and mechanisms in peer learning. *International Journal of Educational Research*, *37*(5), 403-423.
42. Silvia, P. J., Winterstein, B. P., Willse, J. T., Barona, C. M., Cram, J. T., Hess, K. I., Martinez, J. L., & Richard, C. A. (2008). Assessing creativity with divergent thinking tasks: Exploring the reliability and validity of new subjective scoring methods. *Psychology of Aesthetics, Creativity, and the Arts*, *2*(2), 68–85.
43. Slavin, R. E. (1990). Research on cooperative learning: Consensus and controversy. *Educational Leadership*, *47*(4), 52-54.
44. Topping, K. J. (2005). Trends in peer learning. *Educational Psychology*, *25*(6), 631-645.
45. Topping, K., & Ehly, S. (1998). *Peer-assisted learning*. Routledge.
46. Torrance, E. P. (1970). Influence of dyadic interaction on creative functioning. *Psychological Reports*, *26*(2), 391–394.
47. Weidner, T. G., & Popp, J. K. (2007). Peer-Assisted Learning and Orthopaedic Evaluation Psychomotor Skills. *Journal of Athletic Training*, *42*(1), 113-119.