Effects of Comparison and Explanation on Analogical Transfer

Brian J. Edwards[1] (Brian.Edwards@U.Northwestern.Edu), Joseph Jay Williams[2] (Josephjaywilliams@Stanford.Edu), Dedre Gentner[1] (Gentner@Northwestern.Edu), Tania Lombrozo[3] (Lombrozo@Berkeley.Edu)

[1]Department of Psychology, Northwestern University, 2029 Sheridan Road – 102 Swift Hall, Evanston, IL 60208 USA
[2]Office of the Vice Provost for Online Learning and Graduate School of Education, Stanford University, Littlefield 253, 365 Lausen Street, Stanford, CA 94305 USA
[3]Department of Psychology, University of California, Berkeley, 3210 Tolman Hall, Berkeley, CA 94720 USA

Abstract

Although comparison and explanation have typically been studied independently, recent work suggests connections between these processes. Three experiments investigated effects of comparison and explanation on analogical problem solving. In Experiment 1, explaining the solutions to two analogous stories increased spontaneous transfer to an analogical problem. In Experiment 2, explaining a single story promoted analogical transfer, but only after receiving a hint that may have facilitated comparison. In Experiment 3, irrelevant stories were interspersed among the two story analogs to block unprompted comparison; prompts to compare were effective, but prompts to explain were not. This pattern suggests that effects of explanation on analogical transfer may be greatest when combined with comparison.

Keywords: Comparison; explanation; analogical transfer; problem solving; learning.

Introduction

Making comparisons and generating explanations can have robust effects on learning. The value of these processes in learning contexts, along with their centrality and ubiquity in everyday cognition, have inspired rich but largely separate literatures studying comparison and explanation (for reviews, see Gentner, 2010, on analogy and comparison; Lombrozo, 2012, on explanation).

Comparison is the process of identifying similarities and differences between two cases. According to structure-mapping theory, comparison operates by a process of structural alignment based on finding common relational structure (Gentner, 1983; Gentner & Forbus, 2011; Gentner & Markman, 1997). As such, comparison is helpful for acquiring abstract relational schemas and for discovering deep relational commonalities between cases (e.g., Gick & Holyoak, 1983; Loewenstein, Thompson, & Gentner, 2003).

Generating explanations (hereafter, "explanation") consists of a number of related phenomena, including answering "why" and "how" questions. Explanation can support learning through a variety of mechanisms, including promoting deeper processing and helping learners detect gaps and inconsistencies in their knowledge (for a review, see Fonseca & Chi, 2011). Explanation can also affect learning by encouraging learners to seek broad patterns and unifying principles that apply to multiple cases (Williams & Lombrozo, 2010; Williams, Lombrozo, & Rehder, 2013). For example, Williams and Lombrozo (2010) found that participants who explained why a set of robots belonged to their respective categories were more likely than control participants to discover an abstract rule that could be used to accurately categorize all robots.

The view that engaging in explanation can lead people to search for principles that apply to multiple cases – an implication of Williams and Lombrozo's (2010) "subsumptive constraints" account – suggests synergy between comparison and explanation. Specifically, in order to determine whether a principle that applies to one case also applies to another case, comparing the two cases may be useful, or even necessary. Edwards, Williams, and Lombrozo (2013) investigated this possibility in a category learning task similar to that of Williams and Lombrozo (2010); participants who received explanation prompts reported doing significantly more *comparison* processing than participants who received control prompts.

The findings that generating explanations can stimulate spontaneous comparison and that comparison may be a key mechanism by which generating explanations supports learning provide evidence for a relationship between comparison and explanation and raise the question of *how* these processes might work together to support learning. In one study, Gadgil, Nokes-Malach, and Chi (2012) found that comparing learner-generated and expert explanations helped participants detect errors in *systems of relations* between beliefs in addition to helping them notice errors in individual beliefs. More broadly, the Edwards et al. (2013) and Gadgil et al. (2012) studies suggest that combining comparison and explanation may yield even greater learning benefits than engaging in just one of these processes.

In the present work, we investigate the relationship between comparison and explanation in analogical problem solving. We chose this domain for two reasons. First, analogical transfer is a hallmark of learning because it represents the ability to generalize knowledge from one's past experience to situations with novel surface features but a shared underlying structure. Second, both comparison and explanation have been shown to play important roles in supporting analogical problem solving (Gick & Holyoak, 1983; Needham & Begg, 1991).

In a seminal study, Gick and Holyoak (1983) found that students who compared two analogous stories were more likely to spontaneously transfer the solution principle to a novel scenario than those who studied one analogous story (plus an irrelevant control story). Catrambone and Holyoak (1989) extended these findings by showing that participants who were prompted to compare two analogs achieved greater transfer than those who read the same two analogs, but were not prompted to compare (see also Loewenstein et al., 2003).

There is also evidence that generating explanations can boost analogical transfer. Needham and Begg (1991) found that participants who were asked to explain the solution to a puzzle-like problem were more likely to transfer the solution to an analogous problem than control participants who studied the solution to prepare for a memory test.

In the present study, we investigated the roles of comparison and explanation in analogical problem solving. In Experiment 1, participants read two analogs and performed a comparison task, an explanation task, both tasks, or a control task. All participants then attempted a transfer problem. Experiment 2 asked whether effects of explanation on analogical transfer would extend to a situation in which participants received just one analog (and thus could not engage in comparison), and also attempted to replicate previous work finding that comparison increases analogical transfer. Experiment 3 evaluated the effects of comparison and explanation on analogical transfer in a revised protocol in which participants studied two analogs and two irrelevant stories, which was designed to reduce unprompted comparison between the story analogs in the explanation and control conditions.

Experiment 1

Methods

Participants Four-hundred-thirty-one adults participated online via Amazon Mechanical Turk. An additional 165 adults were tested, but were excluded because they failed a "catch trial," performed poorly on comprehension questions, or had previously participated in a similar experiment. In all experiments, the proportion of excluded participants did not vary across conditions.

Materials The materials were taken from Gick and Holyoak's (1983) study. There were two analogous stories, the *fortress story* and the *oil well fire story*, and a transfer problem, the *tumor problem* (Duncker, 1945). Both story analogs and the transfer problem could be solved using the same principle: dividing a large force into several smaller forces, and simultaneously using the smaller forces from different directions to destroy a central target.

Procedure The procedure consisted of a *study phase* followed by the *transfer problem*. Each participant began the study phase by reading the fortress story followed by the oil well fire story. After reading each story, participants answered true/false comprehension questions about that story. Each participant was then randomly assigned to study both stories in one of four study-prompt conditions. The story or stories at which a prompt was directed were always redisplayed on-screen above the prompt. The total study time (five minutes) was matched across conditions.

<u>Comparison Prompt:</u> "What are the *similarities and differences* between the problems faced in these stories and how they were resolved?" (300 seconds, both stories).

<u>Explanation Prompt:</u> "*Explain* the problem faced in this story and how it was resolved." (150 seconds per story).

<u>Both Prompts:</u> Participants responded to both the comparison (150 seconds, both stories) and explanation prompts (75 seconds per story); the order of these prompts was randomized across participants.

<u>Control Prompt:</u> "*Write out your thoughts* as you study the problem faced in this story and how it was resolved." (150 seconds per story).

Next, participants received the transfer problem and were given a maximum of five minutes to solve this problem. After submitting their solution, participants were asked whether they had thought of using the solutions to the fortress and oil well fire stories to solve the tumor problem. Participants were then given a hint that these solutions might be useful for solving the tumor problem, and had the option to try to solve the tumor problem again.

As a manipulation check, we then asked participants to report how much comparison and explanation they engaged in when studying the story analogs. In all experiments, these data confirmed that comparison and explanation prompts significantly increased self-reported comparison and explanation processing, respectively. Due to space, however, these data are not discussed further.

Finally, participants answered end-of-study demographic questions, reported whether they had previously done a study with similar materials, and received a "catch trial" that tested whether they were reading the instructions.

Coding[1] Each attempted solution to the tumor problem was coded as 1 (correct), 0 (incorrect), or "unsure." Across experiments, one percent of responses were coded as "unsure" and were not analyzed. A response was coded as "correct" if it mentioned (1) using multiple non-high-intensity rays, and either (2) using the rays simultaneously or (3) using the rays from different directions.

Results and Discussion

Only 19% of participants made the optional second attempt to solve the tumor problem; thus, we only analyzed spontaneous (before-hint) solutions. A log-linear analysis of *Explanation task (Yes/No) × Comparison task (Yes/No) × Solved the tumor problem (Yes/No)* found that performing the explanation task made participants significantly more likely to solve the tumor problem, $\chi^2(1) = 6.31$, $p = .012$.[2] In

[1] All responses were analyzed by at least one blind coder. A subset of the data was also independently analyzed by a second blind coder and disagreements were resolved by discussion. Reliability was 95%.

[2] Among participants who received both comparison and explanation prompts, the order of these tasks did not have a

contrast to previous and predicted effects, however, the comparison task did not have a significant effect on tumor problem performance, $\chi^2(1) = 0.65$, $p = .42$ (see Fig. 1).

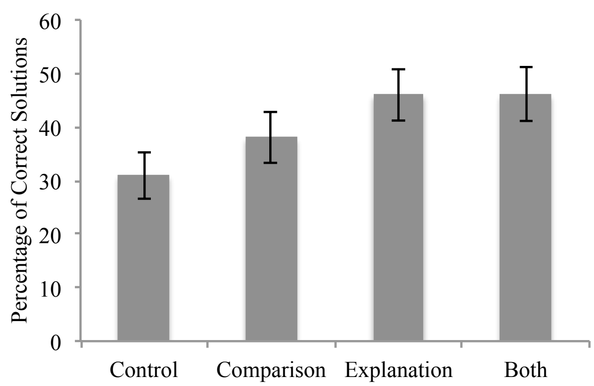

Figure 1: % of participants solving tumor problem in Exp. 1. In all figures, error bars indicate +/- 1 SE.

One possible reason that we did not find significant effects of prompting comparison is that the two story analogs were presented back-to-back and participants read both stories before responding to the study prompts. Thus, participants who did not receive comparison prompts may have noticed similarities between the stories, even though they weren't instructed to compare them.

Despite this limitation, the data from Experiment 1 are informative in that they provide further evidence of a role for explanation in spontaneous analogical transfer. In particular, the observation that unprompted comparison may have been easy raises an intriguing possibility. Explanation participants may have done so well on the tumor problem (in fact, as well as participants who received both comparison and explanation prompts) in part because they also engaged in comparison processing, regardless of whether they were asked to do so. If this view is correct, the benefits of explaining a single analog versus a control task should be relatively weak because there is no opportunity for comparison. Experiment 2 explored this hypothesis, and additionally, sought to replicate the well-established result that comparing two analogs promotes analogical transfer.

Experiment 2

Methods

Participants One-thousand adults participated online via Amazon Mechanical Turk. An additional 521 participants were tested, but were excluded. The exclusion criteria were the same as in Experiment 1.

Materials The materials were the same as in Experiment 1.

significant effect on tumor problem performance, $\chi^2(1) = 1.78$, $p = .18$. Thus, we collapsed the data across task order.

Procedure Each participant was randomly assigned to one of five study conditions as follows.

Baseline Condition: Participants only received the transfer problem.

One-Analog Explanation Condition: Participants read one of the two analogs and responded to the prompt "*Explain* the problem faced in this story and *explain* how it was resolved."

One-Analog Control Condition: Participants read one of the two analogs, but did not receive the explanation prompt.

Two-Analog Comparison Condition: Participants read both analogs and responded to the prompt "What are the *key parallels* between the problems faced in these stories and how they were resolved?"

Two-Analog Control Condition: Participants read both analogs, but did not receive the comparison prompt.

Participants had a maximum of six minutes to respond to each study prompt, but were allowed to advance earlier if they wished. Additionally, we randomized which story one-analog participants received and the order in which two-analog participants received the two stories.

In all conditions, after reading and studying the stories, but before receiving the transfer problem, participants completed a 10-item anagram task. The anagram task served as a buffer between the study phase and transfer problem to create a temporal gap and make transfer more difficult.

Next, participants received the transfer problem and were given a maximum of five minutes to solve the problem. In all conditions except baseline, after participants attempted the tumor problem they received the hint and made a second attempt to solve the tumor problem. The structure of the hint and second attempt were similar to Experiment 1, except that the second attempt was mandatory. To ensure that participants took some time to think about the hint, we also required that they spend at least one minute on the second attempt. After participants completed the second attempt, they answered two basic comprehension questions about the transfer problem; participants who answered either question incorrectly were excluded from the analyses.

We then asked participants in the one-analog and two-analog conditions to report how much explanation they engaged in when studying the stories, and additionally asked two-story participants to report how much comparison they engaged in. Finally, participants answered the same end-of-study questions as in Experiment 1.

Results and Discussion

We first analyzed whether the proportion of participants solving the tumor problem before the hint differed across conditions. This is the key index of spontaneous analogical transfer. To analyze these data, we conducted a series of log-linear analyses of *Study Condition × Solved the Tumor Problem (Yes/No)* (see Fig. 2). Comparison participants were significantly more likely than one-analog control participants to solve the tumor problem, $\chi^2(1) = 20.0$, $p < .001$, replicating Gick and Holyoak (1983). However, in contrast to Catrambone and Holyoak (1989), we did not find an advantage of a comparison task over a two-analog control condition, $\chi^2(1) = 0.94$, $p = .33$. There was also no significant difference between the proportion of explanation and one-analog control participants who solved the tumor problem, $\chi^2(1) = 0.28$, $p = .60$. Not surprisingly, receiving more analogs improved performance: two-analog control participants were significantly more likely than one-analog control participants to solve the tumor problem, $\chi^2(1) = 12.8$, $p < .001$, and one-analog control participants were significantly more likely than baseline participants to solve the tumor problem, $\chi^2(1) = 8.62$, $p = .003$.

Analysis of participants' ratings of the amount of comparison that they engaged in when studying the stories suggests that unprompted comparison may have diluted the (weak) effects of prompting comparison. Although comparison participants reported more comparison than two-analog control participants $t(353) = 7.81$, $p < .001$, even control participants reported moderate amounts of spontaneous comparison ($M = 4.39$ on a 1-7 scale, $SD = 2.00$). Furthermore, self-reported comparison among two-analog control participants was marginally positively correlated with before-hint tumor problem performance, $W(1) = 3.54$, $p = .060$ (and significantly positively correlated with total tumor problem performance, $W(1) = 5.36$, $p = .021$). These data suggest that unprompted comparison may have helped control participants solve the tumor problem. If so, then the results are consistent with prior findings of the efficacy of comparison processing for achieving analogical transfer.

Next, we examined the total proportion of participants who solved the tumor problem, either spontaneously or after the hint to use the prior stories. The only significant difference across study conditions was that explanation participants were more likely than one-analog control participants to solve the tumor problem, $\chi^2(1) = 4.23$, $p = .040$.

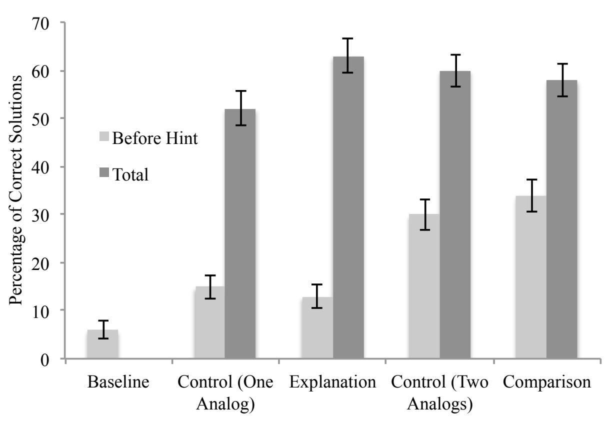

Figure 2: % of participants solving tumor problem in Exp. 2.

One hypothesis for why explanation participants were more likely to solve the tumor problem than one-analog control participants in total, but not before receiving the hint, is that the hint acted as a cue to compare the tumor problem and the story analog that participants read previously. The *combination* of having previously explained and then subsequently comparing the analog and transfer problems may have contributed to their superior performance after receiving the hint. While control participants likely performed a similar comparison after the hint, deeper processing or more abstract encoding may have led explanation participants to benefit more from the comparison. These results are consistent with the intuition that in Experiment 1, explanation participants performed well because they performed both explanation and comparison processing.

In Experiment 3, we modified the procedure by including distractor stories to address the possibility that spontaneous comparison in the two-analog control condition overwhelmed the effects of prompts to compare.

Experiment 3

Participants in all conditions read two irrelevant stories interspersed among the two story analogs. Additionally, Experiment 3 more closely mirrored the Gick and Holyoak (1983) procedure by presenting the initial four stories as if they were a separate study from the phase containing the tumor problem. We predicted that with these changes, Experiment 3 would replicate previous work showing that comparison supports analogical transfer relative to *reading* two analogs without a prompt to compare. Adding the irrelevant stories also allowed us to test the hypothesis that making it harder for participants to detect similarities between the story analogs would reduce the benefits of explaining two analogs that we found in Experiment 1.

Methods

Participants Four-hundred-fourteen adults participated via Amazon Mechanical Turk. An additional 184 adults were tested, but were excluded from the analyses. The exclusion criteria were the same as in the previous experiments.

Materials The materials consisted of four study stories plus the tumor problem. Two of the stories were the fortress and oil well fire stories from Experiments 1 and 2, and the other two stories were stories about negotiations, the shipment story and the farm story, which shared a common principle between them but were unrelated to the tumor problem (adapted from Loewenstein, Thompson, & Gentner, 1999).

Procedure Each participant was randomly assigned to the comparison, explanation, or control condition.

Comparison Condition: Participants read and compared the fortress and oil well fire stories, and then the shipment and farm stories. The comparison prompt was the same as in Experiment 2.

Explanation Condition: Participants read and explained the first analog, the shipment story, the second analog, and then the farm story. The explanation prompt was the same as in Experiment 2.

Control Condition: Participants read and summarized the first analog, the shipment story, the second analog, and then the farm story. The summary prompt was "*Summarize* the story you just read."

In the explanation and control conditions, the order of the two analogs (the fortress and oil well fire stories) was randomized across participants. In these conditions, the two analogs appeared non-consecutively to make unprompted comparison more difficult. In the comparison condition, the position of the two analogs (left vs. right) was randomized. Participants were given a maximum of six minutes for each explanation and summary prompt, and a maximum of 12 minutes for each comparison prompt.

After studying the stories, participants received instructions for a second experiment to make them think that the tumor problem was unrelated to the four stories. The procedure for the tumor problem, including the second attempt, was the same as in Experiment 2.

After the tumor problem, we evaluated participants' memory for the four stories by asking five true/false memory questions about each of the four stories. Next, participants rated the amounts of comparison and explanation that they engaged in when studying the fortress and oil well fire stories and received the same demographic and catch-trial questions as in Experiments 1 and 2.

Results and Discussion

Log-linear analyses of *Study Condition × Solved the Tumor Problem (Yes/No)* found that before the hint, comparison participants were marginally more likely than control participants to solve the tumor problem, $\chi^2(1) = 3.02$, $p = .082$, but there were no other differences across conditions (Comparison vs. Explanation: $\chi^2(1) = 1.22$, $p = .27$, Explanation vs. Control: $\chi^2(1) = 0.42$, $p = .52$); see Fig. 3. Interestingly, in contrast to Experiment 1, explaining two analogs did not seem to boost analogical transfer, perhaps because the presence of the irrelevant stories made it harder to compare the two analogs. The total proportion of participants who solved the tumor problem (combining before- and after-hint solutions) did not differ across study conditions, $\chi^2(2) = 0.27$, $p = .87$.

Closer inspection of the before-hint data found that although comparison and control participants who received the fire story first performed equally well on the tumor problem, of participants who received the fortress story first, comparison participants outperformed control participants, $\chi^2(1) = 5.88$, $p = .015$. Participants' memory for the two analogs may help explain the effect of study order. Control participants who received the fire story first had better memory than those who received the fortress story first, $t(127) = 2.67$, $p = .009$, and overall, control participants had better memory than comparison participants, $t(256) = 3.21$, $p = .001$. Indeed, among comparison and control participants, a logistic regression of *Solved the tumor problem (Yes/No)* on *Study condition* and *Memory for the relevant stories* found that after controlling for memory, comparison participants were significantly more likely than control participants to solve the tumor problem, $W(1) = 4.03$, $p = .045$. On the assumption that our control condition improved memory for details, rather than being a more neutral baseline, we conclude that Experiment 3 replicated, with Amazon Mechanical Turk participants, the result that comparing two analogs increases analogical transfer.

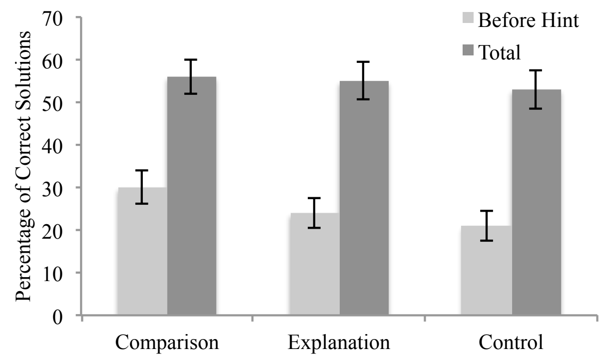

Figure 3: % of participants solving tumor problem in Exp. 3.

As expected, comparison participants were significantly more likely than control participants (50% vs. 34%) to think of using the story analogs to solve the tumor problem, $\chi^2(1) = 7.40$, $p = .007$. However, of participants in these conditions who tried to use the solutions to the story analogs to solve the tumor problem, the proportion who spontaneously solved the tumor problem did not differ across conditions, $\chi^2(1) = 0.11$, $p = .74$. This is consistent with prior findings that (at least for these materials) the benefit of comparison processing during study is to increase spontaneous retrieval of the story analogs, rather than to improve participants' ability to map the solution between the story analogs and the tumor problem. In cases in which the solution principle is more difficult to extract, comparison participants might show both greater retrieval and greater ability to map the solution from base to target.

General Discussion

We investigated the effects of comparison and explanation tasks on analogical problem solving. We found that both types of tasks can promote spontaneous (i.e., before-hint) analogical transfer; however, the effectiveness of these tasks varied considerably across experiments. With respect to comparison, we replicated prior findings that comparing two story analogs led to better performance on an analogous transfer problem than studying a single analog (Experiment 2). However, comparing two analogs was not more effective than reading the same two analogs (Experiments 1 and 2), in contrast to some prior findings (Catrambone & Holyoak, 1989; Loewenstein et al., 2003). Self-reports indicated that unprompted comparison among control participants may have diminished the difference between these two conditions. The results of Experiment 3 support this hypothesis. When irrelevant stories were interspersed to make it more difficult to detect similarities between the two story analogs, comparison participants were significantly more likely than control participants to spontaneously solve the tumor problem (controlling for memory).

With respect to explanation, we found benefits for analogical transfer, but only under limited circumstances. In Experiment 1, explaining two analogous stories increased spontaneous analogical transfer. In Experiment 2, explaining one analog led to greater analogical transfer after a hint, but did not improve spontaneous transfer. In Experiment 3, explaining two analogs did not improve tumor problem performance either before or after the hint.

One hypothesis consistent with these results is that explanation may benefit from comparison processing. That is, engaging in explanation may be most helpful for analogical transfer when participants perform relevant comparisons and are able to find common principles. In Experiment 1, which found the most robust effects of explanation, participants read both analogs before explaining them, making such comparisons easy. In contrast, in Experiment 3, irrelevant stories were placed in between analogs to impede comparison of the story analogs. Here the explanation task did not increase analogical transfer. In Experiment 2, explanation participants outperformed control participants only after participants received a hint to use the story analog to solve the tumor problem; this hint may have served as an invitation to compare the analog and the tumor problem.

Conversely, comparison may benefit from explanation processing. The finding that explaining a story analog led to better post-hint performance than simply reading the same analog suggests that the explanation task supported an encoding that enhanced the effects of the invited comparison between the analog and the tumor problem.

More broadly, the present findings highlight the interconnectedness of comparison and explanation and provide further evidence that comparison is one mechanism by which generating explanations supports learning (see also Edwards, Williams, & Lombrozo, 2013). We hypothesize that in the present experiments, engaging in comparison helped learners notice common relational structure across cases, and that engaging in explanation encouraged learners to identify important patterns that could apply to multiple cases. Future work exploring the relationship between comparison and explanation in other domains can examine the nature and generality of interactions between comparison and explanation, and can shed further light on both the unique aspects of each process and how these processes may work together to enhance learning.

Acknowledgments

We thank Amy Lee for assistance with coding. The research was supported by an NSF Graduate Research Fellowship (BJE), ONR grant N00014-13-1-0470 (DG), and NSF grant DRL-1056712 (TL).

References

Catrambone, R., & Holyoak, K. J. (1989). Overcoming contextual limitations on problem-solving transfer. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *15*, 1147-1156.

Duncker, K. (1945). On problem solving. *Psychological Monographs*, *58*.

Edwards, B. J., Williams, J. J., & Lombrozo, T. (2013). Effects of explanation and comparison on category learning. In M. Knauff, M. Pauen, N. Sebanz, & I. Wachsmuth (Eds.), *Proceedings of the 35th Annual Conference of the Cognitive Science Society*. Austin, TX: Cognitive Science Society.

Fonseca, B., & Chi, M. T. H., (2011). The self-explanation effect: A constructive learning activity. In Mayer R., & Alexander, P. (Eds.), *The Handbook of Research on Learning and Instruction*. Routledge Press.

Gadgil, S., Nokes-Malach, T. J., & Chi, M. T. H. (2012). Effectiveness of holistic mental model confrontation in driving conceptual change. *Learning and Instruction*, *22*, 47-61.

Gentner, D. (1983). Structure-mapping: A theoretical framework for analogy. *Cognitive Science*, *7*, 155-170.

Gentner, D. (2010). Bootstrapping the mind: Analogical processes and symbol systems. *Cognitive Science, 34*, 752-775.

Gentner, D., & Forbus, K. (2011). Computational models of analogy. *WIREs Cognitive Science*, *2*, 266-276.

Gentner, D., & Markman, A. B. (1997). Structure mapping in analogy and similarity. *American Psychologist*, *52*, 45-56.

Gick, M. L., & Holyoak, K. J. (1983). Schema induction and analogical transfer. *Cognitive Psychology*, *15*, 1-38.

Loewenstein, J., Thompson, L., & Gentner, D. (1999). Analogical encoding facilitates knowledge transfer in negotiation. *Psychonomic Bulletin & Review*, *6*, 586-597.

Loewenstein, J., Thompson, L. & and Gentner, D. (2003). Analogical learning in negotiation teams: Comparing cases promotes learning and transfer. *Academy of Management Learning and Education*, *2*, 119-127.

Lombrozo, T. (2012). Explanation and abductive inference. In K.J. Holyoak and R.G. Morrison (Eds.), *Oxford Handbook of Thinking and Reasoning* (pp. 260-276), Oxford, UK: Oxford University Press.

Needham, D. R., & Begg, I. M. (1991). Problem-oriented training promotes spontaneous analogical transfer: Memory-oriented training promotes memory for training. *Memory and Cognition*, 19, 543-557.

Williams, J. J., & Lombrozo, T. (2010). The role of explanation in discovery and generalization: evidence from category learning. *Cognitive Science*, *34*, 776-806.

Williams J. J., Lombrozo, T., & Rehder, B. (2013). The hazards of explanation: overgeneralization in the face of exceptions. *Journal of Experimental Psychology: General*, *142*, 1006-1014.