Title
Analogical Reasoning During Hypothesis Generation: The Role of Surface Competition During Access and Transfer

Journal
Proceedings of the Annual Meeting of the Cognitive Science Society, 46(0)

Authors
Leon, Sabina
Rivas, Leandro E.
Trench, Maximo

Publication Date
2024

Peer reviewed

Analogical Reasoning During Hypothesis Generation: The Role of Surface Competition During Access and Transfer

Sabina V. Leon (sabinav.leon@gmail.com)
Department of Psychology, National University of Comahue
Quintral 1250, 8400, Bariloche, Rio Negro, Argentina

Leandro E. Rivas (leandro.rivas@crub.uncoma.edu.ar)
Department of Psychology, National University of Comahue and CONICET
Quintral 1250, 8400, Bariloche, Rio Negro, Argentina

Máximo Trench (maximo.trench@crub.uncoma.edu.ar)
Department of Psychology, National University of Comahue and CONICET
Quintral 1250, 8400, Bariloche, Rio Negro, Argentina

Abstract

Behavioral studies and computer simulations of analogical retrieval suggest that the availability of surface matches in long-term memory (LTM) hinders the spontaneous retrieval of purely structural analogs. We investigated whether this competition effect still holds during hypothesis-generation, a goal-driven activity that entails a more profound and sustained consideration of the target situation. In two experiments, we obtained that the availability of a less isomorphic but more superficially similar item did not complicate retrieving a structural analog, thus suggesting that goal-driven activities such as hypothesis generation aid participants in overcoming the activation of a structurally suboptimal analog in working memory, as compared to pragmatically impoverished activities such as reading the target situation. However, the activation of the surface match hindered the successful application of structural matches that were successfully retrieved. Results render a more nuanced picture of the role of surface similarities in analogical thinking, traditionally restricted to the retrieval stage.

Keywords: analogy; retrieval; transfer; hypothesis generation

Introduction

Two situations can be considered analogous to the extent that their corresponding elements are organized by similar systems of relations and roles (i.e., *structural similarity*, Gentner, 1983). During epistemically-relevant situations as diverse as solving a problem, generating a causal explanation, predicting an outcome or devising a persuasive argument, a potentially useful heuristic consists in retrieving analogous cases (*base analogs*) from long-term memory (LTM). Through a mapping between the elements that play corresponding roles in the base analog and the current situation (i.e., the *target analog*), causal structures can be tentatively projected onto the target. Even though the action of comprehending an analogy does not require that the base and the target involve similar objects and object properties (i.e., *surface similarity*), this kind of similarity becomes crucial for retrieving events from LTM.

Within this empirical tradition, the cued-recall paradigm represents the experimental procedure most frequently employed to assess the relative contribution of surface and structural similarity to analogical retrieval. After reading a first series of stories, participants receive a new set of stories bearing different types of similarity with one or more stories of the former series, and are tasked with reporting which stories from the previous phase each new episode reminded them of. With the exception of Raynal et al. (2020), studies following this procedure show that surface similarity exerts a much stronger effect than structural similarity during retrieval (Catrambone, 2002; Gentner et al., 1993, Wharton et al., 1994).

In line with this pattern of behavioral results, traditional computer simulations of analogical retrieval (e.g., ARCS, Thagard et al., 1990; LISA, Hummel & Holyoak, 1997; MAC-FAC, Forbus et al., 1995) have decomposed the retrieval process into two distinct phases: a computationally cheap filter based on superficial similarity, and a more costly algorithm designed to calculate the structural overlap between the target and the candidates submitted by the previous stage. While these models differ in terms of their architectures and representational assumptions (e.g., MAC/FAC uses serial processing over propositional representations, whereas LISA appeals to connectionist-style processing over sub-symbolic primitives), one point of agreement concerns the competitive nature of analogical retrieval, in terms of which the odds of retrieving a specific situation from LTM are negatively affected by the concurrent presence of other stored situations maintaining similarity with the contents of working memory.

Even though the inhibitory effect of similar items in LTM would hold irrespective of the kind of similarity between the target and the competing sources, the direction that bears clearer implications for knowledge transfer concerns the effect of surface matches on accessing distant analogs. As the first filter of most computational models is attentive to surface but blind to shared structure, any surface matches in the memory set will likely contribute to crowding out purely structural matches during early stages of the retrieval process (Gentner et al., 1993, 2009, Trench & Minervino, 2020).

In L. K. Samuelson, S. L. Frank, M. Toneva, A. Mackey, & E. Hazeltine (Eds.), *Proceedings of the 46th Annual Conference of the Cognitive Science Society.*

Despite the intuitive appeal of the competition effect as derived from computational models, behavioral evidence regarding the interference of surface matches on distant analogical transfer is scarce, and hardly generalizable to real-life activities. In a recent study following a cued-recall paradigm, Trench et al. (2020) placed a distant analog in competition with source situations maintaining different degrees of surface similarity with the target. While objects-only matches resembled the target only in terms of objects and object properties, *mere-appearance matches* shared objects as well as first-order relations with the target. However, first-order relations were arranged in a way that yielded the structure of mere-appearance matches non analogous to that of the targets. Across two experiments, distant analogs were less retrieved when competing with objects-only matches than when competing with mere-appearance matches, demonstrating that increased surface competition hinders analogical retrieval.

In light of this preliminary evidence, a sensible research question concerns whether the detrimental effect of surface competitors generalizes to pragmatically-richer activities for which analogical transfer can play an important role. In the cued-recall procedure, where participants have to report any remindings that take place while reading the target passage, the fact that any activation of a previous story suffices to cope with the received instructions makes it rather unlikely that the working memory representation of the target will persist beyond the retrieval of an initial episode (in previous studies, retrieval of more than one story ranged between 5% and 8%). In contrast to these rather passive reminding instructions, goal-driven activities such as problem-solving, hypothesis generation, argumentation, or prediction entail an exploration of the target structure that is more intensive and sustained. From this analysis it follows that embedding the target within goal-driven activities might lead participants to either avoid the activation of surface competitors altogether, or else to discard them as irrelevant so as to relaunch a search process with better chances of yielding the retrieval of distant analogs.

Our choice of hypothesis generation over other goal-driven activities followed several considerations. Despite the obvious relevance of analogical reasoning for the prospects of *generating* hypotheses, most studies linking analogy to causal explanation focus of how students understand —rather than generate— analogical explanations. Beyond filling a gap in the analogy literature, a reason for selecting hypothesis-generation has to do with the fact that the typical targets of hypothesis generation (scientific phenomena) belong to knowledge domains that tend to be neatly organized into subfields that could be employed as promising "search areas" (Ripoll, 1998) wherein to search for analogous cases. As an example, reflecting on phenomena related to "heat transfer" readily invites considering whether valuable pieces of information can be found in neighboring topics of physics, such as *electric conductivity* or *osmosis*. Hence, beyond the intrinsic value of employing an activity that has seldom been the target of analogy research, we reasoned that hypothesis-generation could represent a particularly advantageous activity for the prospects of overcoming the automatic retrieval of a surface competitor.

Even in those cases where the reasoner succeeds in accessing a structural analog despite the retrieval of a surface competitor, the subsequent stages of mapping, inference and adaptation still pose a non-negligible challenge when it comes to transferring unmapped base information onto the target analog (Anolli et al., 2001; Rivas et al., 2023). As opposed to the surface items employed in psychological experiments, which can be crafted to avoid any structural overlap with the target, in realistic situations it is often the case that surface-level resemblances correlate with hidden commonalities at deeper, more structural levels (the *kind-world hypothesis*, Gentner & Maravilla, 2018). To the extent that retrieved items maintaining surface similarity with the target will also tend to maintain some concomitant degree of structural overlap, their inadequacy for exporting explanatory structures onto the target may sometimes remain unnoticed. Based on these ecological considerations, we built our surface matches to be less structurally similar to the target phenomenon than the distant analogs, but to maintain some degree of structural similarity as well. Our second objective was therefore to determine whether the concomitant retrieval of structurally suboptimal sources maintaining higher surface similarity with the target reduces the odds of extrapolating explanatory structures from comparatively more appropriate analogs that were successfully retrieved.

Experiment 1

Method

Participants A total of 96 undergraduate students (Age M = 29.4; SD = 10.16, 76% women) volunteered to participate in the study after receiving an email invitation. Invitations were issued until obtaining responses from 88 participants, as dictated by a G*****Power analysis (Faul et al. 2007), set to detect a medium effect size with power = .8 and confidence = .95. Participants were randomly assigned to two conditions that differed in whether the distant analog read during the learning phase competed (N = 46) or did not compete (N = 50) with an experimentally provided surface match.

Materials and Procedure Upon electronically signing an informed consent, the learning phase of the experiment was presented to participants of both groups as a reading-comprehension activity. During this phase, participants received three short passages, each one describing a situation with a somewhat counterintuitive outcome plus a causal explanation. After reading each text, participants had to answer three comprehension questions without rereading the passage. For both conditions, the second passage (i.e., the distant analog) described a rare Indonesian rodent whose specimens reproduced at intervals of exactly four years. The provided explanation for this infrequent pattern of reproduction involved the fact that during pregnancy, the pancreas of female pangolins secretes a substance that inhibits future ovulations, and which takes exactly four years to get reabsorbed (see the complete materials in Table 1).

This fictitious situation was especially crafted to maintain structural similarity with one of the phenomena to be presented during the following phase (i.e., the fact that rubber trees bloom every nine years), such that an explanatory hypothesis for the target phenomenon could be built upon the base analog´s explanation by postulating the secretion and slow reabsorption of a substance that inhibited further blooming.

In the "surface competition" condition, the base analog was surrounded by a filler story that was structurally and superficially unrelated to the target phenomenon, as well as by a surface competitor that, as compared to the second passage, maintained higher surface overlap but less structural similarity with the cyclic 9-year blooming phenomenon. This surface competitor depicted a variety of tree that had the potential of renewing its protective bark under very favorable environmental conditions, as when several consecutive years of high precipitations lead to an unusual accumulation of organic material in the ground. In order to serve as a surface competitor, the key elements of this story maintained higher degrees of taxonomic similarity with the elements of the target phenomenon (i.e., the rubber trees) than did those of the distant analog (i.e., the pangolins). However, its causal explanation could only partially explain the nine-year periodicity of the booming (i.e., the dependence of external circumstances could explain "rarely-occurring" but not "exactly-timed" iterations).

In the "no surface competition" condition, participants received the distant analog surrounded by two filler stories whose entities and relational structures were unrelated to those of the target phenomenon.

Table 1: Base and target situations, Experiment 1

Base analog: The pangolin is and Indonesian mammal of scaly skin, whose meat is highly praised. Its scarcity is related to the strange fact that they reproduce at intervals of four years. It turns out that during gestation, the pancreas of pregnant females accumulates a substance that inhibits further ovulations, and which reabsorbs very slowly. Four years after a gestation, when this substance has been completely reabsorbed, they ovulate and reproduce, a process that gets repeated every four years.

Surface similarity distractor: The guatambu is a tree whose wood is covered by a thick bark that protects it from termites and other potentially dangerous parasites. As years pass, this bark starts to deteriorate due to fungi, microorganisms, and other biological agents. In exceptional circumstances, as after consecutive years of rainfalls above 300mm, the soil gets covered by a thick layer of leaves and fallen trunks, which produce high levels of nitrogen. When these circumstances arise, guatambus capitalize on the excess of nutrients for replacing their old bark by a new one.

Target Analog. The rubber tree is a tropical species with very curious blooming features. As the majority of other plants, it booms during the summer, when temperature and rains increase. However, once a plant has bloomed, it will take nine years to bloom again. What could be the reasons behind the fact that they bloom every nine years?

After a section on demographic information intended to reinforce a contextual separation, the transfer phase was presented to participants as a hypothesis-generation activity. After an instructional text on causal explanations that included two non-analogical examples of explanatory hypotheses, participants received a filler phenomenon bearing neither surface nor structural similarity with the target analog, and were allotted 8 minutes to provide plausible explanations. Participants were told that their hypotheses needed to be defensible and potentially true, but that accordance with the scientifically accepted account of the presented phenomenon was not required. As with the demographic information section, the inclusion of this filler phenomenon before the target phenomenon was intended to increase the temporal separation between the processing of the base analogs/surface competitors and that of the target situation.

Upon submitting explanations for this filler phenomenon, participants were allotted 8 minutes to generate plausible causal explanations for the target situation. A subsequent section asked participants to report whether any of the stories presented during the reading-comprehension activity had come to mind, even if briefly, while either reading or generating explanations for the periodic blooming scenario. Participants responding affirmatively were further asked to indicate which situation (or situations) they were reminded of during the work with the blooming phenomenon.

Scoring. Two judges blind to condition sorted participants' explanations into one of three categories. Responses were classified as derived from the distant analog whenever they related the blooming to the secretion of a slowly-reabsorbing substance that inhibited subsequent blooming. They were classified as derived from the surface competitor when they related the blooming to any external circumstances (e.g., extraordinary levels of rainfall, sunlight, temperature, etc.) that did not exhibit an exact periodicity. All other responses were classified as "other". Judges agreed in 94% of the cases, and resolved cases of disagreement by discussion.

Results and Discussion

In the no competition condition, 48% of participants reported having been spontaneously reminded of the pangolin passage (distant analog) while generating hypotheses for the blooming phenomenon. This retrieval rate did not differ from that of the competition condition, where 34.78% of participants were spontaneously reminded of the distant analog, $\chi^2(1, 96) = 1.72$, $p = .189$.

The observed lack significant differences stands in contrast with recent results obtained with memory tasks measuring spontaneous retrieval of distant base analogs during pragmatically-void activities such as passively reading the target situation. A straightforward interpretation of this contrast with memory tasks would be that the goal-driven nature of our hypothesis generation task might have aided participants in either avoiding the unwanted activation of the surface competitor in working memory, or else in eventually overcoming the effects of its conscious activation on the retrieval of the distant analog.

Table 2: Retrieval and use of similarity matches, Experiment 1

	Retrieval		Application	
	DA	SC	DA	SC
Competition (N = 46)	34.78 (16)	15.22 (7)	33.33 (1)	33.33 (1)
No Competition (N = 50)	48 (24)	N/A	37.5 (9)	N/A

Note. DA: Distant analog; SC: Surface competitor. Numbers between parentheses represent absolute values. Application percentages of DAs were calculated out of the subset of participants who retrieved the DA (no competition condition) or the DA *and* the SC (competition condition). Application percentages of SCs were calculated out of participants who retrieved both the SC and the DA.

Among participants of the no competition condition who retrieved the base analog, 37.5% transferred its explanation to the target. In the competition condition, participants who recalled the distant analog *and* the surface competitor (N = 3) had numerically similar chances of transferring the base explanation onto the target (33.3%). However, the low retrieval rate of the surface competitor precluded carrying out statistical analyses.

One likely explanation for the low retrieval rates of the surface competitors might have to do with the fact that the target and the distant analog could be captured by a quasi-lexicalized schema-governed category (i.e., "long cycle"). As the activation of relational categories promotes a more uniform encoding of structural features (Jamrozik & Gentner, 2020; Raynal et al., 2018), they could have facilitated access to further exemplars sharing structural features with the target.

In order to render structural analogs less retrievable than the surface competitors—and therefore more alignable with prior research—, in a subsequent experiment we modified the base and target phenomena of Experiment 1 in such a way that they no longer belonged to a relational category. By way of rendering the surface competitor at least as retrievable as the structural analog, we would be able to assess not only the extent to which its presence in the memory set affects the retrieval of the structural analog, but also the extent to which its activation in working memory complicates extrapolating the explanatory structure of the base analog onto the target phenomenon.

Experiment 2

Method

Participants. A total of 89 undergraduate students (Age M = 28.96; SD = 10.73. 77% women) volunteered to participate in the study after receiving an email invitation. Invitations were issued until obtaining responses from 88 participants, as dictated by a G*Power analysis (Faul et al. 2007) set to detect a medium effect size with power = .8 and confidence = .95. Participants were randomly assigned to the competition (N = 43) and the no competition conditions (N = 46).

Materials and Procedure. The base and target passages involved the same elements as in Experiment 1, with the difference that the phenomenon at stake was not a "long cycle", but instead an alternative structure wherein the first occurrence of certain process prevents said process from ever reoccurring. The distant analog described a rare Indonesian rodent whose low population was related to the fact that during pregnancy, the pancreas of female pangolins secreted a substance that inhibited future ovulations, and which remained in the organism during the rest of their life (see complete texts in Table 3). The secretion of a slowly-decaying inhibitory element that persisted during the lifetime of an individual could be potentially reused to generate a satisfactory explanation for the target phenomenon, which involved a species of trees whose attractive flowers bloom only once, despite the fact that the trees live for several years.

As in Experiment 1, the key elements of the surface competitor were taxonomically more similar to the key target elements than to those of the distant analog. However, its explanatory structure was comparatively less optimal for accounting for the target phenomenon (see materials in Table 3). The surface competitor involved a type of tree that could potentially renew its protective bark in response to external conditions such as a series of consecutive years of extraordinary rain, but which currently fail to renew their bark during their lifetime due to the fact that these extraordinary levels of precipitation no longer take place. The inadequacy of its causal structure for explaining the target phenomenon had to do with the fact that the current absence of the conditions that favor the blooming would leave the initial blooming unexplained. The distracter items and the procedure followed during the learning and the transfer phases were identical to those of Experiment 1.

Table 3: Base and target situations, Experiment 2

Base analog: The pangolin is and Indonesian mammal of scaly skin, whose meat is highly praised. Its scarcity is related to the strange fact that during gestation, the pancreas of pregnant females accumulates a substance whose chemical properties inhibits further ovulations. Even though this substance gets reabsorbed, reabsorption is so slow that high quantities remain hosted in the pancreas throughout the mothers' life. For this reason, female pangolins that have bred will not get pregnant for a second time.
Surface similarity distractor: The guatambu is a tree whose wood is covered by a thick bark that protects it from dangerous parasites. As years pass, this bark starts to deteriorate due to fungi and other biological agents. In exceptional circumstances, as after consecutive years of rainfalls above 300mm, the soil gets covered by a thick layer of leaves and fallen trunks, which produce high levels of nitrogen. Historically, guatambus capitalized on this unusual increase of nutrients for generating a new bark that would protect them for years to come. But as a consequence of the massive deforestation that took place during the nineteenth century, such precipitations ceased to occur. For this reason, actual guatambu trees grow and die without ever changing their bark.
Target Analog. The rubber tree is a tropical plant from South America. Its violet flowers are very striking, and also possess a very particular sweet smell. But even more striking is its blooming pattern. Upon blooming for the first time, they won't bloom again throughout their life cycle. What could be the reason behind the fact that after a first blooming, they won't bloom again?

Coding. Two judges blind to condition sorted participants' explanations into one of three categories. Explanations were classified as derived from the distant analog whenever they related the blooming to the secretion of a substance that inhibited subsequent blooming, and which remained in the organism throughout its lifecycle. Responses were classified as derived from the surface competitor when they related the lack of a subsequent blooming to any external circumstances (e.g., extraordinary levels of rain, sunlight, temperature, etc.) that no longer exist. All other responses were classified as "other". Judges agreed in 91% of the cases, and resolved cases of disagreement by discussion.

Results and Discussion

As opposed to Experiment 1, where the surface competitor was seldom retrieved, participants in the competition condition were reminded of the surface competitor in more than half of the cases (see Table 4). Despite this higher conscious activation of the surface competitor, spontaneous retrieval of the distant analog was still not lower in in the competition than in the no competition condition, 41.86% vs 41.3, $\chi^2(1, 89) = 0$, $p = 1$. These results suggest that the more profound and sustained processing of the target that takes place during hypothesis generation might have aided participants not only in overcoming the competition effect implicitly exerted by the mere presence of surface competitors in the memory set (as in Experiment 1), but also in overcoming its conscious activation in working memory.

More exploratory in nature, a secondary objective of the present research concerned the potential effects of retrieving a surface competitor on the prospects of extrapolating to the target phenomenon the explanatory structure of distant analogs that were successfully retrieved. To address this question, the transfer performance of participants who retrieved the distant analog in the no competition condition was compared with that of participants of the competition condition who retrieved both the distant analog *and* the surface competitor. This analysis revealed that participants who retrieved the distant analog along with the surface competitor were less likely to transfer the distant analog's explanatory structure onto the target phenomenon, 20% vs. 63.16 %, $\chi^2(1, 34) = 6.33$, $p = .012$.

Table 4: Retrieval and use of similarity matches, Experiment 2

	Retrieval		Application	
	DA	SC	DA	SC
Competition (N = 43)	41.86 (18)	51.16 (22)	20 (3)	13.64 (3)
No Competition (N = 46)	41.3 (19)	N/A	63.16 (12)	N/A

Note. DA: Distant analog; SC: Surface competitor. Numbers between parentheses represent absolute values. Application percentages of DAs were calculated out of the subset of participants who retrieved the DA (no competition condition) or the DA *and* the SC (competition condition). Application percentages of SCs were calculated out of participants who retrieved both the SC and the DA.

General Discussion

Based on a wealth of behavioral evidence, computer models of analogical retrieval grant a central role to surface similarities during the retrieval of related content from LTM. The theoretical prediction that available surface matches will render the retrieval of purely structural analogs less likely has recently received support from studies in which the target was framed within pragmatically-impoverished tasks such as reading a passage (Trench et al., 2020). However, it was yet unknown whether the detrimental effect of surface competitors generalizes to pragmatically oriented activities such as argumentation, prediction, problem-solving, and hypothesis generation. We reasoned that as goal-oriented activities involve an analysis of the target situation that is more profound and also more sustained in time, the reasoners would have better chances of overcoming the automatic activation of a surface match in working memory by way of resuming a search for LTM items bearing higher inferential potential.

In both experiments, the retrieval of the structural analog by participants of the competition condition was not statistically lower than that of participants whose base analog did not compete with a surface match in LTM, thus suggesting that the profound and sustained consideration of the target that takes place during goal-driven activities aids participants in overcoming the availability of surface competitors to a greater extent than in pragmatically-void memory tasks.

In a previous study on hypothesis generation, the explicit indication to search for analogous episodes increased the number of distant analogs retrieved by participants. The fact that this effect was larger during hypothesis generation than during problem-solving was interpreted as suggesting that, when seeking for analogs of the typical targets of hypothesis generation (i.e., unexplained scientific phenomena), memory search can capitalize on an agreed-upon compartmentalization of knowledge into fields and subfields (e.g., thinking about heat transfer readily invites neighboring subdomains such as *electric conductivity* or *osmosis*). These promising subfields can serve as "search areas" (Ripoll, 1998) within which search can be circumscribed, thus increasing the likelihood of finding a structural match. Even though participants of the present study were not invited to think of analogous situations, both the nature of the target task and the structure of the target domain might have helped participants of the competition condition in overcoming the eventual activation of a surface match. In the present materials, however, the semantic distance between the base and the target analogs was far from extreme, since a very low retrieval rate in the no competition condition would have yielded a floor effect, thus conspiring against the very possibility of detecting a competition effect. Future studies should address whether the present results still hold with other educationally-relevant activities, and with base analogs that pertain to domains far removed from the target situation.

Even though retrieving a structural match represents a necessary step in the transfer process, participants who retrieve an appropriate analog often fail to extrapolate its structure to the target situation (Anolli et al., 2001; Rivas et al., 2023).

Hence, a second objective of the present study was to assess the extent to which the activation of a superficially similar situation with a suboptimal structure could compromise the successful application of retrieved items bearing a tighter structural isomorphism but less surface overlap with the target. While in Experiment 1 the low retrieval rate of the surface competitors precluded analyzing their effect on transferring the explanatory structure of the structural analogs that were successfully retrieved, in Experiment 2 their retrieval rates allowed for this analysis. Results revealed that among participants who succeeded in retrieving the structural analog, those who also retrieved the surface competitor had significantly lower chances of extrapolating explanatory structure of the more optimal structural analog to the target phenomenon.

At first sight, this result would seem to defy extant computational models of mapping and inference (e.g., SME, Falkenhainer et al., 1989; LISA, Hummel & Holyoak, 1997), which enforce structural consistency between the base and the target. It should be noted, however, that our surface competitors also carried some degree of structural similarity with the target, in a manner consistent with how salient commonalities tend to correlate with deeper, less accessible structural features in the natural world (the *kind-world hypothesis*, Gentner & Maravilla, 2018). Akin to the higher confidence associated with transferring "blank properties" between perceptually-similar category exemplars (see, e.g., Rips, 1975), participants who were in a position to decide between transferring the explanatory structure of the structural analog and transferring that of the surface competitor may have experienced a struggle between the inferential advantage of increased structural isomorphism and that of higher taxonomic proximity. Taken more broadly, these results would seem to promote a conception of the inference stage of analogical reasoning as lying halfway between the traditional account of analogical mapping—centered chiefly on structural consistency— and the traditional wisdom in category-based induction, where surface resemblances across exemplars still play a significant role. Future studies should pursue a more systematic crossing of these two dimensions of similarity, both within hypothesis generation and within other educationally-relevant activities for which analogical transfer represents a promising heuristic.

Acknowledgments

This work was supported by Grants PICT 2019-02542 and PICT 2019-3268 from the National Agency for Scientific and Technological Research (ANPCyT) of Argentina, and by Grant PIP018 from the National Council for Scientific and Technical Research (CONICET).

References

Anolli, L., Antonietti, A., Crisafulli, L., & Cantoia, M. (2001). Accessing source information in analogical problem solving. *Quarterly Journal of Experimental Psychology A: Human Experimental Psychology*, *54*, 237–261.

Catrambone, R. (2002). The effects of surface and structural feature matches on the access of story analogs. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *28*, 318-334.

Falkenhainer, B., Forbus, K. D., & Gentner, D. (1989). The structure-mapping engine: Algorithm and examples. *Artificial Intelligence*, *41*, 1-63.

Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*, 175–191.

Forbus, K., Gentner, D., & Law, K. (1995). MAC/FAC: A model of similarity-based retrieval. *Cognitive Science*, *19*, 141–204

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

Gentner, D., Loewenstein, J., Thompson, L., & Forbus, K. (2009). Reviving inert knowledge: Analogical abstraction supports relational retrieval of past events. *Cognitive Science*, *33*, 1343–1382.

Gentner, D. & Maravilla, F. (2018). Analogical reasoning. In L. J. Ball & V. A. Thompson (eds.) *International Handbook of Thinking & Reasoning* (pp. 186-203). NY: Psychology Press.

Gentner, D., Rattermann, M. J., & Forbus, K. D. (1993). The roles of similarity in transfer: Separating retrievability from inferential soundness. *Cognitive Psychology*, *25*, 431-467

Hummel, J., & Holyoak, J. (1997). Distributed representations of structure: A theory of analogical access and mapping. *Psychological Review*, *104*, 427-466.

Jamrozik, A., & Gentner, D. (2020). Relational labeling unlocks inert knowledge. *Cognition*, *196*, 104146.

Raynal, L., Clement, E., & Sander, E. (2018). Structural similarity superiority in a free-recall reminding paradigm. *Proceedings of the 40th Annual Conference of the Cognitive Science Society* (pp. 2327-2332). Cognitive Science Society.

Raynal, L., Clement, E., & Sander, E. (2020). Are superficially dissimilar analogs better retrieved than superficially similar disanalogs? *Acta Psychologica*, *203*, 102989.

Ripoll, T. (1998). Why this makes me think of that. *Thinking & Reasoning*, *4*, 15-43.

Rips, L. J. (1975). Inductive judgments about natural categories. *Journal of Verbal Learning and Verbal Behavior*, *14*, 665-681.

Rivas, L., Garibotti, G., Mema, J., & Trench, M. (2023). Analogical reasoning during hypothesis generation: The effects of object and domain similarities on access and transfer. *Proceedings of the 45th Annual Conference of the Cognitive Science Society* (pp. 1349-1355). Austin, TX: Cognitive Science Society.

Thagard, P., Holyoak, K. J., Nelson, G., & Gochfeld, D. (1990). Analog retrieval by constraint satisfaction. *Artificial Intelligence*, *46*, 259-310.

Trench, M., & Minervino, R. A. (2020). *Distant connections: The memory basis of creative analogy.* New York: Springer.

Trench, M., Rivas, L., Díaz, M., & Minervino, R. A. (2020). Spontaneous and voluntary analogical retrieval during problem-solving and hypothesis generation. *Proceedings of the 42nd Annual Meeting of the Cognitive Science Society* (pp. 1384-1390). Austin, TX: Cognitive Science Society.

Trench, M., Tavernini, L. M., Olguín, M. V., & Minervino, R. A. (2020). Accessing distant analogs over superficial matches: How efficient is the architecture of our retrieval systems? *Proceedings of the 42nd Annual Meeting of the Cognitive Science Society* (pp. 2074-2080). Austin, TX: Cognitive Science Society.

Wharton, C. M., Holyoak, K. J., Downing, P. E., Lange, T. E., Wickens, T. D., & Melz, E. R. (1994). Below the surface: Analogical similarity and retrieval competition in reminding. *Cognitive Psychology*, *26*, 64–101.