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Lucas Raynal, Evelyne Clément, Emmanuel Sander

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Lucas Raynal (lucasraynal@gmail.com)
Paragraphe Lab, EA 349, University Cergy-Pontoise
Avenue Marcel Paul, 92230 Gennevilliers, FRANCE

Evelyne Clément (evelyne.clement@u-cergy.fr)
Paragraphe Lab, EA 349, University Cergy-Pontoise
Avenue Marcel Paul, 92230 Gennevilliers, FRANCE

Emmanuel Sander (emmanuel.sander@paris8-univ.fr)
Paragraphe Lab, EA 349, University Paris 8, Department of Psychology
2 Rue de la liberté, 93526 Saint-Denis Cedex 02, FRANCE

Abstract

The predominant view concerning determinants of analogical retrieval is that it is preferentially guided by superficial cues. In order to test the cognitive plausibility of a structural similarities-based retrieval, we constructed a story-recall task in which life-like scenarios shared structural correspondences. In Experiment 1, we showed that such structural similarities induce retrievals when the participant had several source candidate situations sharing superficial similarities with the target cue. Experiment 2 was designed to test whether the encoding was sufficiently oriented on structural similarities to drive retrievals, even if the participants possess only one source candidate situation with superficial matches in memory. The results of the two present experiments lead us to conclude that in some contexts, abstract encoding induces a superiority of structural similarities over superficial ones in retrieval. Further implications for analogical retrieval approaches are discussed.

Keywords: Analogy; analogical retrieval; structural similarity; abstract encoding; story-recall task

Introduction

Analogy has been identified as a key process to perceive the conceptual structure of a new situation by importing it from a familiar analog representation (Gentner, 1983; Gick & Holyoak, 1983). Most studies are consensual that the mapping process permitting this transfer is preferentially based on structure rather than surface correspondence. In other words, when comparing two analogs, subjects do not rely on similarities in terms of objects or object attributes, but instead tend to focus on common abstract relations. Figure 1 provides an illustration of a target cue story sharing a structural correspondence with a superficially dissimilar analog source candidate situation ("*making a deal to avoid a bad situation"*), and a surface correspondence with a superficially similar disanalog source candidate situation belonging to the same semantic domain (*raptors, tailfeathers, etc*).

Target cue story

Karla, an old hawk, lived at the top of a tall oak tree. One afternoon, she saw a hunter on the ground with a bow and some crude arrows that had no feathers. The hunter took aim and shot at the hawk but missed. Karla knew the hunter wanted her feathers so she glided down to the hunter and offered to give him a few. The hunter was so grateful that he pledged never to shoot at a hawk again. He went off and shot deer instead.

Superficially dissimilar analog source candidate situation

Once there was a small country called Zerdia that learned to make the world's smartest computer. One day Zerdia was attacked by its warlike neighbor, Gagrach. But the missiles were badly aimed and the attack failed. The Zerdian government realized that Gagrach wanted Zerdian computers so it offered to sell some of its computers to the country. The government of Gagrach was very pleased. It promised never to attack Zerdia again.

Superficially similar disanalog source candidate situation

Once there was an eagle named Zerdia who donated a few of her tailfeathers to a sportsman so he would promise never to attack eagles. One day Zerdia was nesting high on a rocky cliff when she saw the sportsman coming with a crowsbow. Zerdia flew down to meet the man, but he attacked and felled her with a single bolt. As she fluttered to the ground Zerdia realized that the bolt had her own tailfeathers on it.

Figure 1: Situations sharing different types of similarity in Gentner, Ratterman & Forbus (1993)

Types of similarity implicated in the retrieval of a source representation in memory are the main issues debated in the literature. The predominant view is that the retrieval of a source candidate situation critically depends on superficial similarities, whereas the influence of structural similarities seems more peripheral (Gentner, 1983; Gentner, Ratterman & Forbus, 1993; Gick & Holyoak, 1983; Trench & Minervino, 2015). In Gentner and Colhoun's (2010) words: "Relational retrieval can be said to be the Achilles' heel of our relational capacity. There is considerable evidence that

similarity-based retrieval, unlike the mapping process, is more influenced by surface similarity than structural similarity." However, opposite assertions have arisen in the literature, attributing a major influence to structural similarities, even overcoming that of surface similarities (Blanchette & Dunbar, 2000; Dunbar & Blanchette, 2001; Hofstadter & Sander, 2013; Kretz & Krawczyk, 2014). The aim of this paper is to demonstrate that structural matches have a greater influence than superficial ones in the retrievals of life-like situations. This will be shown by creating a competition between source candidate situations sharing either exclusively superficial or structural similarities with the target cue (Figure 2 illustrates this intended feature composition). Before considering the current experiments, we report the major findings stemming from several experimental paradigms.

	Analog source candidate situations	Disanalog source candidate situations
Structural similarity	X	
Superficial similarity		X

Figure 2: Correspondences between target cues and critical source candidate situations intended in Experiment 1 and 2

Analogical Problem Solving

In the problem solving domain, a common experimental design to study analogical retrieval via analogical transfer is the source-target paradigm (Gick & Holyoak, 1983; Holyoak & Koh, 1987). A source problem situation is first proposed with its solution, then an analog target problem is given to be solved. To measure the role of surface correspondence in access, the surface of the source problem is manipulated to either match or not with the target one. The retrieval is considered to have occurred when the participant detects similarities between the target problem and the source problem without further hints from the experimenter, leading to the transfer of the resolution procedure from the source to the target. Results have shown that retrieval is high when the source is both superficially and structurally similar to the target. More precisely, the similarities in terms of the problems' story theme have appeared to be a crucial determinant in access (Ross, 1987). Inversely, superficially dissimilar analog source problems are seldom retrieved by the participants (Gick & Holyoak, 1983). Studies on problem solving have also demonstrated that structural similarities can, in certain circumstances, have a role in retrieval: when two source analogs are presented jointly to be compared, their critical solution principle can be retrieved when faced with the target (Catrambone & Holyoak, 1989). Also, retrievals are reported to be more frequent when the two superficially dissimilar analog problems share structural similarities at a less abstract level (Holyoak & Koh, 1987).

Story-Recall Paradigm

Another frequently used paradigm is the story-recall task (Gentner et al., 1993; Wharton, Holyoak & Lange, 1996; Catrambone, 2002). A set of short text stories are presented as source candidates for the retrieval before the introduction of target cue situations which share various similarities with them (Figure 1). Within a problem solving paradigm, the problems generally share the same structure since it is the transfer of an abstract solution being investigated. This is not systematically the case in the story-recall paradigm since the situations are chosen to create a competition between source candidate situations possessing exclusively the surface or exclusively the structure in common with the target cue (Gentner et al., 1993). This paradigm showed superficially similar disanalogs were retrieved significantly more often than superficially dissimilar analogs, leading to the conclusion that superficial similarity is the main factor implicated in access.

Wharton, Holyoak, Downing, Lange, Wickens & Melz (1994) argued that the minor role attributed to structural matches in story-recall tasks could be due to the fact that only one source candidate, the superficially similar disanalog, shares some semantic features with the target cue. One can note that in real-life conditions, several source candidate situations, corresponding in superficial features with the perceived situation, are generally available in memory. The authors observed that structural similarities may play a certain role in access because when the analog source candidate also shares some superficial similarities, it is better retrieved than the concurrent source candidate possessing only superficial similarities with the target cue. Structural similarities also seem to play a certain role in access when they are implemented without superficial matches: the retrieval of a superficially dissimilar source candidate is higher when it shares structural features with the target cue (Wharton et al., 1996). However, the role of structural similarities in access has only been shown when two source candidates shared the same amount of surface correspondence. Hence, the reviewed works did not demonstrate the superiority of structural similarities in access, since it would require showing that superficially dissimilar analogs are better retrieved than superficially similar disanalogs.

Production Paradigm

Challenging the ecological nature of traditional experimental conditions (unfamiliar source and target situations, short familiarization time, restrained pool of source candidates), further research focused on the retrieval of situations encoded prior to the experiment in real-life conditions (Blanchette & Dunbar, 2000; Dunbar & Blanchette, 2001; Kretz & Krawczyk, 2014). With this configuration, a high structural overlap was generally observed between the source and the target cue situation. For instance, expert discourse in scientific domains (politics, biology, economics) exhibited predominance for structural analogies, though sometimes also sharing a superficial

correspondence. Those findings were replicated in experimental conditions with a production paradigm, where participants who were allowed to select their own sources of analogy retrieved significantly more semantically distant analogs than superficially similar analogs (Blanchette & Dunbar, 2000). In other words, those findings not only advocate for the major role of structural similarity but also for the weak impact of superficial similarity when accessing an analog. However, Trench & Minervino (2015) pointed out that the sources provided by the participants could be invented rather than real memories, and that superficially dissimilar analogs could be more common in memory than superficially similar ones. They tested the potential that while controlling the availability and number of the two types of concurrent source candidates, findings obtained from usual source-target and story-recall paradigms would be replicated when the participant generates analogical retrievals from her or his own experiences. They proposed target situations with either superficial and structural, or solely structural similarities with their memories. In accordance with prior findings, participants more often proposed superficially similar analogs than superficially dissimilar ones. In another study using this paradigm, situations retrieved by management consultants provided with target situations embodying an original negotiation principle manifested only superficial matches (Gentner, Loewenstein, Thompson & Forbus, 2009). Contrary to previous studies using the production paradigm, this experiment reflects a marginal tendency to access structurally similar source situations. These results, in sharp contrast with the ones obtained by Dunbar and Blanchette (2000), indicate that the natural settings of the encoding condition of one of the analog is not in itself the critical parameter influencing the type of retrieval. Namely, whereas it probably promotes the abstract encoding of this analog situation, the access to its structural matches with the other analog which is still provided by the experimenters is not guaranteed.

Encoding through abstract concepts

When faced with a target cue situation, the fail to retrieve an analog situation is generally interpreted as a defect of abstract encoding of the two situations (Gick & Holyoak, 1983; Gentner et al., 2009). If the participant is unable to grasp the structure of the situations, the abstract similarities could not be used as a cue to retrieve. Indeed, only if the participant is incited to compare either two source analogs or two target analogs, he might extract a schema sufficiently abstract, and subsequently perceive this schema in a superficially dissimilar analog, in the context of the retrieval.

However, even if the schema extracted from the situation is not abstract enough so that the similarities introduced between the analogs by the experimenter will be detected, it cannot be claimed that the encoding of a situation is purely concrete and literal (Hofstadter & Sander, 2013). Whereas a wealth of stimulations is permanently available in our environment, one has to select the properties relevant to make sense of the situations. This cannot be done by processing every perceptively available superficial piece of information. Instead, the situation's understanding depends on the properties (whether perceptual or abstract) that are compatible with the conceptual structure in construction and on the neglect of those which are not.

We suggest that familiar concepts' evocation during the encoding is a critical point to account for the abstract information raised by perceived situations. This idea is congruent with findings revealing that source analog problems that participants usually fail to retrieve in experiments are better accessed by expert participants (Novick, 1988). When experts have a familiar concept to highlight the abstract properties of these situations, the novice does not have this conceptual door toward the structure. This reveals that the novice participant has not elaborated the specific concept that allows for the encoding of the structure of complex problem situations necessary for the structurally-based retrieval of this type of situations. However, it is very likely that he/she has acquired an expertise in daily-life situations, where one systematically has to deepen the encoding until elementary abstract concepts are established, such as "making a deal", "bad faith", "lie", "authenticity", "prosocial behavior" and so on, to produce adapted behaviors. The activation of these concepts should highlight the structure underlying some daily-life situations in a way that elicit structurally-based retrieval. Whereas most studies have focused on abstract inter-domain analogies that a novice could rarely access, we aim at investigating analogies between situations inspired from social scenarios that can be experienced in different domains of daily-life.

Experiment 1

In order to demonstrate the superiority of structural similarities over superficial similarities in retrieval, we conducted a first experiment where those two types of similarities were in competition in the retrieval of a source situation candidate. In that way, a story-recall task was used so as to control for the highlighting of the structure underlying both the analog source candidate situation and the target cue situation.

Method

Material

Social scenarios inspired from Wharton et al. (1996) involving life-like contexts were used. Although the objects of the analog situations were clearly divergent, they shared very similar role at the required level of abstraction for making sense of the stories. In the analog pair reported in Figure 3 for instance, both stories relate the setting of a social competition between two characters (*rival cookers* or *classmates*) having the same goal (*turnover* or *seducing someone*) and *an unusual way to put an end to it by helping the competitor to enhance her/his critical ability* (*improve Lorenzo's pizza dough* or *looking after Diane's appearance*). If those situations are not directly taken from the participant's

experience, s/he still can use her/his general knowledge about social relations to encode such scenarios.

In order to make sure that the two types (superficial or structural) of similarities with the target cue were never confounded in a same source situation, superficially similar source stories structure clearly diverge from the target ones. In this way, contrasting with previous works (e.g. Gentner et al., 1993), disanalogs are not modified versions of a same structure story, but describe structurally different scenarios.

Wharton et al. (1994) noticed that when semantic correspondence was not only present between the source disanalog and the target cue, the artificial saliency of the superficial matches decreased and resulted in a weaker influence on access. In their experiment, the concurrent superficially similar source candidates were the analog and the disanalog. As previously indicated, we aim at isolating the influence of structure and surface similarities by implementing them in different source candidates. Hence, we multiplied the number of source candidates sharing surface features with the target cue by introducing three superficially similar disanalogs. To respect a symmetry between the number of semantically close and distant source candidates, we also introduced three superficially dissimilar source candidate situations (the analog sharing structural correspondence, and two unrelated distractors).

Target cue story

Luigi holds a pizza truck in a very popular place. Lorenzo, another ambulant pizzaiolo, has placed his truck just beside Luigi's and is detrimental to his turnover. Luigi realizes the dough of Lorenzo's pizzas is bland. Luigi spontaneously gives his personal recipe to Lorenzo so as he can enhance the quality of his product. Since then, his pizza dough is amazingly tasty. The same evening, Lorenzo declares to Luigi that in order to show him how much he found his intention was nice, he will move his truck in another sector, far from this one.

Superficially dissimilar analog source candidate situation

Julie is in love with Victor, her classmate, and she is getting closer to him in order to seduce him. But Diane joins the class in the middle of the year and also has a crush on Victor. Julie remarks that Diane was not very aware of her style and proposes her some relooking advices, showing her fashion photos and taking her for shopping. Diane now looks very cute and chic. Diane is so grateful that she tells Julie that she would stop flirting with Joe.

Superficially similar disanalog source candidate situation

In a market place, the truck called « At Alessandro & Fabio's » has various choices of homemade pizzas. The important clientele going there is fond of the authentic atmosphere steaming from this stand held by the two happy looking men in Italian traditional suits. However, once they will have left this selling space, the two men will go to another market place after taking care of wearing German traditional clothes to sell sausage specialties. The sign will display « At Hans and Hendrich's ».

Figure 3: Examples of stories used in the Experiment1

Procedure and experimental design

The first two pages of a booklet presented the 6 source stories, then a blank page separated them from the last page comporting the target cue situation. Under each source story was a 5 points scale inviting participants to assess the ease they had to imagine the scene while reading it. As recommended by Wharton et al. (1996), this was done to promote a deep treatment of the situations. The dependent variable was the source retrieved during the reading of the target cue situation.

It was indicated that the task took around 10-15 minutes to fulfill but no time limitations was imposed. After they agreed to participate, participants were given the booklet. They were invited to read the instructions available in the first page. The target cue situation was presented on the last page, followed by the solicitation to indicate if they were reminded of one of the previous situations. If it was the case, they had to restitute any element they could remember about it.

Participants

34 participants (25 women and 9 men, mean age 23.8 years) accepted to take part in the experiment in University libraries (Paris 5 and Paris 8). They were all fluent French speakers.

Results and discussion

Access credit was attributed to the source candidate for which the participant recalled word content. If content word from more than one source was reported, the source containing the more content words in common was credited. If the participant explicitly reported more than one source despite the instruction, his response was excluded. 3 responses were not analyzed for this reason.

Analyses were drawn on a comparison between the superficially and structurally similar source candidates that were retrieved. Structurally similar source candidate situations were much more retrieved (84.61 %) than superficially similar disanalog source candidate situations (15.39 %, see Figure 4). This difference reaches high significance (X^2 (1, N=29)=12.46; P<0.001)[1].

In real-life condition, one generally has in memory multiple source candidates sharing similarities in terms of superficial objects with the target cue situation. The results reveal that when a pool of semantically similar source candidate situations is available in memory, but those situations do not preserve the structure of the target cue, the

[1] 4 participants chose one of the two distractors or did not report any retrieval and were not included in the analyses

retrieval is preferentially guided by structural matches with sources of a distant semantic domain. However, our results cannot help us identifying whether the structural matches of daily-life scenarios are sufficiently blatant to drive the retrieval when only one concurrent source candidate belongs to the same semantic domain as the target cue. Experiment 2 was designed in order to answer this question.

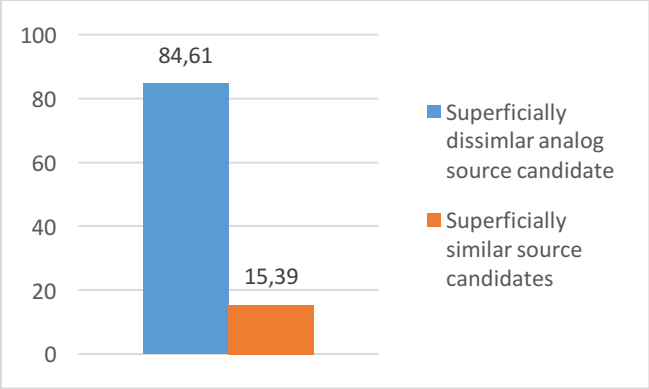

Figure 4: % of retrievals of structurally versus superficially similar source candidates in Experiment 1

Experiment 2

Method

Material

Six source candidate situations were proposed before the target cue situation (taken from experiment 1): 4 unrelated stories (distractors), one superficially similar disanalog story (taken from Experiment 1) and a superficially dissimilar analog story (taken from Experiment 1, c.f. Figure 3). Hence, the design was more similar to the one used in traditional recall tasks (Gentner et al., 1993), though it differs in the isolation of structural or superficial similarities in different source candidate stories that are in competition.

Procedure and experimental design

The procedure and experimental design were the same as in Experiment 1.

Participants

67 students (52 women and 15 men, mean age 20.8 years) accepted to take part in the experiment during a class (University Paris 8).

Results and discussion

3 responses could not be interpreted since several source candidate situations were reported despite the instruction asking for only one.

[2] 2 participants chose one of the two distractors or did not report any retrieval and were not included in the analyses

Again, analyses were focused on the comparison between surface and structure similarities-based retrievals. As illustrated in Figure 5, the superficially dissimilar analog source candidate was significantly more retrieved than the superficially similar disanalog source candidate (respectively 81.25% and 18.75%, X^2 (1, N=62)=22.41, p<0.001)[2].

These results share a similar pattern with the ones obtained from Experiment 1. This comparison induces that the presence of multiple situations belonging to the same semantic domain as the target cue was not a determinant factor promoting the superiority of structural similarities in retrieval. Instead, the fact that our stimuli depicted daily-life situations might have been a critical parameter so that the participants may have rely on the abstract structures of the scenarios as retrieval cues.

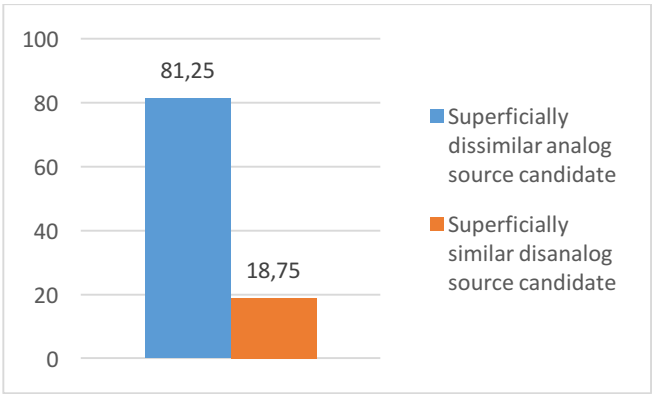

Figure 5: % of retrievals of structurally versus superficially similar source candidates in Experiment 2

Conclusion

In Experiment 1, the superiority of structural similarities in retrieval was observed while the source analog was in competition with several source candidates sharing exclusively surface features with the target cue. As noted by Wharton et al. (1994, 1996), providing participants with only one source candidate sharing objects with the target cue may provoke its retrieval. However, in Experiment 2, providing participants with only one surface matching source candidate in competition with the superficially dissimilar analog did not reduce the proportion of structural similarity-based retrievals. Thus, structural similarity-based retrievals are predominant when the situations experimentally provided are close to the ones that are encountered in daily-life.

Experimental studies have widely converged on the conclusion that retrieval is driven by superficial similarities. However, as the analog situations that have been mainly studied are unfamiliar for the participants, the latter conclusion cannot be applied to the more ecological retrievals that are processed in daily-life. Indeed, in analogical problem

solving, analog problems share a highly abstract resolution principle (Gick & Holyoak, 1983; Ross, 1987). Alternatively, the nature of retrieval can be better informed when meaningful structural similarities are set between situations potentially encountered by the participants in their familiar environment. Under these conditions, the participant's knowledge allows to encode familiar relations that constitute cues for retrieving former episodes, while surface features may be neglected (Novick, 1988; Hofstadter & Sander, 2013). Indeed, a filter has to operate in order to identify the relevant properties constitutive of a concept that allows to make sense of the situation.

Some authors have claimed that the commonly observed surface similarity-based retrieval was not so detrimental to our cognition since situations sharing surface generally also share structure (the *kind world hypothesis*; Gentner & Medina, 1998; Trench & Minervino, 2015). It is noticeable indeed that objects in our environment usually interact in regular ways and have typical relations (Bassok, Wu & Olseth, 1995). For instance, situations involving two pizzaioli in the same place potentially induce very closed relations, such as a competition between them (Figure 3). Two situations sharing both surface and structure can only be more structurally similar than two surface dissimilar situations sharing only structure at a certain level of abstraction. Yet, it has been taken as granted for advocating the superficially driven retrieval view that retrievals of structurally and superficially similar situations were more frequent than only structurally similar ones (Trench & Minervino, 2015). An attempt to introduce a source candidate sharing only surface and no structure with the target cue has been made in story-recall paradigms (Gentner, 1993). Yet, a closer look at the stimuli (Figure 1) makes apparent that the superficially similar disanalog source candidate situations systematically still shared some relational features with the target cue (Wharton et al., 1996). Their structures are highly similar (*making a deal to avoid a bad situation*) until opposite conclusions at the end of the stories (*betrayal* or *respect of the deal*). However, a set of objects still can induce a heterogeneous panel of relations (e.g. two pizzaioli: *rivalry*, *friendship*, etc), while different types of objects can induce very similar relations (e.g. a loving couple can also induce the relation *rivalry* for instance, c.f. Figure 3). In our experiments, dissociating object similarities and similarities in terms of familiar relations into different source candidate situations demonstrated that it is not the objects in themselves that drive access, but rather the familiar structural relations that link them.

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