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Structural similarity superiority in a free-recall reminding paradigm

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Abstract

The high proportion of retrievals of situations sharing surface similarity in previous experiments gave rise to the view that surface similarity predominantly drives access. In contrast, we claim that the retrievals of those situations are due to the structural similarity they still preserved. We tested our alternative *structural superiority hypothesis* while isolating the influence of structural and surface similarity by assessing whether participants predominantly retrieve situations sharing only structural similarity (superficially dissimilar analogs) or situations sharing only surface similarity (superficially similar disanalogs). Contrary to previous experiments instructing participants to produce analogies, we used a free-recall reminding paradigm in which participants had to recall any situations a target cue reminded them of. Results demonstrated that a greater proportion of participants predominantly retrieved situations sharing only structural similarity than situations sharing only surface similarity. Results are discussed relatively to the current debate regarding the retrieval of analogs preserving or not surface similarity.

Keywords: analogical retrieval; structural similarity; abstract encoding; free-recall reminding paradigm

Introduction

Imagine that someone tells you that, after saying to herself every day that tomorrow she will go to the Do It Yourself store to buy the lightbulb she needs, she finally bought it at least two weeks later. Would you be likely to be reminded of that moment when you had to answer an e-mail, what you finally did many days later, after saying to yourself several times a day that you would send it later during the day? Or would you be more inclined to retrieve this situation where you broke a lightbulb in a friend's house and bought him one back the same day in the Do It Yourself store? A great deal of research led in the field of analogy has aimed to assess whether analogies can be spontaneously processed between a present (a target cue) and a stored situation (a source candidate situation, such as between the *buying a lightbulb* and the *answering an e-mail* previous situations) sharing an abstract pattern of relations (structural features, e.g. *an activity that should be done now is postponed*), even though they imply different objects and object attributes (surface features, e.g. *lightbulb* and *Do It Yourself Store* as opposed to

e-mail and *computer*). Most of it has converged on the implausibility to retrieve superficially dissimilar analogs demonstrating that retrieval, being predominantly oriented towards surface similarity, often leads to access mere-appearance matches sharing surface but no structural similarity (Gentner, Ratterman & Forbus, 1993, e.g. the *breaking a lightbulb at a friend's house* situation). Following Forbus, Ferguson, Lovett & Gentner (2017), "*memory retrieval is strongly influenced by content, and only weakly influenced by relational structure*" (p 1164). Determining the type of similarity that is used to retrieve is fundamental to understand human cognition since it is tightly linked to the question of the nature of the encoding (Gentner, Loewenstein, Thompson & Forbus, 2009; Hofstadter & Sander, 2013), the usefulness of reminding for transfer (Gick & Holyoak, 1983) and the possibility of an experience-based conceptual development (Hofstadter & Sander, 2013; Loewenstein, 2017).

Source-target paradigms

The question of whether structural or surface similarity is dominant in retrieval has initially been addressed through source-target paradigms where source candidate situations are presented before target cue situations sharing structural, surface or both similarities.

In classical story-recall tasks, some source candidate situations share only structural similarity while others are supposed to share only surface similarity with the target cue. Results showed that superficially similar disanalog source candidate situations were mainly retrieved whereas superficially dissimilar analog source candidate situations were only marginally accessed, leading to the conclusion that surface similarity is more influential than structural similarity in retrieval (Gentner et al, 1993). The main effect of surface similarity on retrieval has been replicated in studies using similar methodologies (Catrambone, 2002), whereas the secondary role attributed to structural similarity varied across studies. Namely, it has been shown that a structurally similar source candidate situation, sharing surface similarity or not, is preferentially retrieved over a structurally dissimilar source candidate situation sharing the same level of surface similarity (high level in Wharton, Holyoak, Downing, Lange,

Wickens & Melz, 1994; low level in Wharton, Holyoak & Lange, 1996).

In problem-solving, the influence of structural and surface similarity has been mainly addressed through the comparison of spontaneous transfer between two analog problems sharing surface similarity or not. A source problem is provided to the participant with its solution before the analog target problem has to be solved. A recurrent finding is that without hint to use the source problem solution, transfer rarely occurs between two superficially dissimilar analog problems (Gick & Holyoak, 1983; Gentner, Loewenstein & Thompson, 2003; Gentner, Loewenstein, Thompson & Forbus, 2009). Adding surface similarity between the two analog problems strongly increases the amount of transfer (Keane, 1987).

In sum, data from story-recall tasks indicate that mere-appearance matches are preferentially retrieved over superficially dissimilar analog source candidate situations, and results from analogical problem-solving suggest that recalling a source problem with its solution is highly dependent on the presence of surface similarity.

Real-world analogies

As opposed to studies using classical experimental paradigms, observational studies led out of the experimental context have put emphasis on the importance of structural similarity when retrieving analog source situations. Their methodology generally consists in extracting analogies that are generated during expert discussions and analyzing their structural and superficial components. Dunbar's (1997) study has shown that although the great majority of the analogies produced by molecular biologists in their lab are intradomain analogies, they contain a deep structural similarity. Similar findings were obtained when analyzing analogies generated by both experts and novices in management who had to solve business management problematic situations (Bearman, Ball & Ormerod, 2007). Christensen and Schunn (2007) found an important proportion of interdomain analogies in engineers' discussions working on the design of medical plastics, almost as frequent as intradomain analogies. Analogies extracted from discussions between experts in economy were also equally distributed among intradomain and interdomain (Kretz & Krawczyk, 2014). Further analysis demonstrated that superficially similar features were rarely mentioned between the source and the target cue situations. Blanchette and Dunbar (2000) showed that a high majority of the analogies used in newspapers dealing with the referendum on the Quebec independence were taken from a distant semantic domain from the one of politics. Hence, observational studies introduced two major considerations concerning the role of surface and structural similarities in analogical retrieval. First, superficially similar analogs represented an important proportion among the source situations that were used (Dunbar, 1997; Bearman, Ball & Ormerod, 2007). Second, analogies without surface similarity were more frequent than in laboratory studies, suggesting that structural similarity may play a greater role in access than

previously shown (Dunbar & Blanchette, 2000; Christensen & Schunn, 2007; Kretz & Krawczyk, 2014).

Production paradigms

The contrasted findings stemming from experimental and observational studies motivated researchers to identify the critical factors allowing subjects to drive structurally-based retrievals in ecological conditions, while constraining participants to use superficial cues to retrieve source candidate situations in experimental settings. In this spirit, Blanchette and Dunbar (2000) created a production paradigm to bring more ecological validity in an experimental context. In this production paradigm, participants had to produce analogies using familiar source situations from their experience instead of unfamiliar source candidate situations which are presented during the experiment. In that study, participants were asked to act as political consultants to produce analogies with familiar situations that could help convincing the population that a target political strategy (pro-zero or anti-zero deficit strategy) is well-founded. In sharp contrast with previous findings from experimental studies, they found that 67% of the analogies generated by the participants did not share surface similarity with the target situation, belonging to a distant semantic domain from the one of politics. From this result, the authors suggested that the dominance of surface similarity that had been observed until then was a consequence of the unfamiliarity of the experimental stimuli, the impossibility to rely on one's own source of analogy and the absence of a goal inciting the analogizer to use deeper cues to retrieve.

However, their findings were recently contested by Trench and Minervino (2015) who pointed out that the source situations proposed by the participants could have been the consequence of analogs' creations rather than analogical retrieval of real memories. Replicating the production paradigm's design, the researchers provided either a superficially similar or dissimilar analog target cue situation to elicit the retrieval of a source candidate situation from the participant's experience and which presence in memory is controlled. For instance, the retrieval of *having consumed so much of a new food with the consequence of becoming disgusted of it* or of *having played a video game so much with the consequence of getting fed up with it* was tested by instructing participants to find an analogy to prevent someone who enjoys passion fruit so much that he is interested in incorporating it into cheesecakes, toppings and daiquiri from doing so. Results showed that retrievals of the critical analog source candidate situation were more frequent when it was superficially similar than when it was not. The authors concluded that the superiority of structural similarity in retrieval reported in Blanchette and Dunbar's studies was due to a lack of experimental control, and that their results reconcile with the ones obtained with traditional experimental paradigms in terms of the dominance of surface similarity in retrieval.

The implausibility of surface similarity-based access

Findings revealing the difficulty of retrieval based on structural similarity are generally explained in terms of an encoding that would be focused on surface features. This position can be summed up with Gentner et al.'s (2003, p 393) words: "*In short, our ability to take advantage of our prior experiences is highly limited. One explanation for the low degree of appropriate recall is that people often encode cases in a situation-specific manner, focusing mainly on their surface features*" (see also Forbus, 2017 and Loewenstein, 2017). Such a surface level encoding would seem very disabling since it implies that our comprehension of the situations rarely goes beyond the consideration of the situation's objects. Also, a retrieval based on these objects would lead to access many mere-appearance matches which structure is sterile to help understanding a present situation.

However, structural features of the situations are encoded when they involve relations which are usually encountered in daily-life. For instance, it has been shown that solution transfer between isomorphic problems sharing an abstract "random distribution principle" is mediated by the presence of objects assigned to humans in both problems, since it enables to grasp a common "get" familiar structure (Bassok, Wu & Olseth, 1995). These data suggest that the inability to drive structurally-based access could be the consequence of the unfamiliarity of the structures which are implemented between the superficially similar analogs in the experiments (Blanchette & Dunbar, 2000; Hofstadter & Sander, 2013). In familiar situations, such as the ones we encounter in daily-life, our encoding might go beyond the objects we perceive to grasp the relations they display in light of the usual relations we have learned to associate to them (Popov, Hristova & Anders, 2017). Referring to the *answering an e-mail* or the *buying a lightbulb* situations we presented above, it seems likely that the activation of familiar concepts such as *activities that must be done*, *lazyness* and *postponing* allows one to encode the structure "*an activity that should be done now is postponed*" and thus permits structurally-based retrievals.

Superficially similar analogs' retrievals

In Blanchette and Dunbar's (2000) and Trench and Minervino's (2015) studies, the question of the dominance of structural versus surface similarity has been addressed by directly asking participants to generate analogies (after explaining them what an analogy is), and then comparing the proportion of superficially similar versus dissimilar analogs. However, using this methodology to assess whether surface or structural similarity predominantly drives spontaneous access may present the bias of inciting participants to use structural similarity in their retrievals. In addition, the preponderance of superficially similar over superficially dissimilar analogs' retrievals, as shown in some observational studies (Dunbar, 1997; Bearman et al., 2007) as in Trench and Minervino's (2015) production study, cannot lead to clear conclusions regarding the type of similarity that elicited them. Notably, while Dunbar and

Blanchette (2001) insist on the role of structural similarity in superficially similar analogs' retrievals ("It is important to note that even though the scientists were basing their analogies on sources and targets within the domain of biology, the analogies were based upon underlying sets of structural relationships rather than any superficial similarity between clams and plasmodium", p. 336), Trench and Minervino (2015) claim that the preponderance of superficially similar analogs' retrievals is the hallmark of the surface similarity superiority ("our results run counter to the claim that the dominance of superficial similarities in retrieval is rooted in the artificiality of the tasks and materials used in traditional experiments", p. 21; see also Bearman, 2007 and Loewenstein, 2017 for similar conclusions).

As suggested by Gentner et al. (1993), a way to compare the influence of structural versus surface similarities in retrieval is to compare the retrievals' frequency of mere-appearance matches and superficially dissimilar analog source candidate situations. As mere-appearance matches are only superficially similar, their retrieval can only be the consequence of a surface-similarity based retrieval, and as superficially dissimilar analog source candidates are only structurally similar, their retrievals can only be provoked by a structural similarity-based retrieval. In traditional experimental contexts, it has been shown that mere-appearance matches' retrievals were preponderant (Gentner et al., 1993). However, a closer look at the stimuli used in these experiments reveals that structural similarity is still present in mere-appearance matches. For instance, Karla the hawk target cue situation relates the story of a hawk which gives feather to a hunter with a bow who is grateful and promises never to attack eagle. The mere-appearance match deals with an eagle which gives tail feathers to a sportsman with a crossbow who is grateful and promises never to attack eagle, but who finally shoots at the eagle. Hence, the mere-appearance match also shares a structure with the target cue (e.g. *make a deal to avoid a bad situation*) although an additional twist is presented in the eagle story (the sportsman finally breaks the deal). Raynal, Clément and Sander (2017) demonstrated that when structural and surface similarities are isolated in different source candidate situations, superficially dissimilar analog are better retrieved than superficially similar disanalog source candidate situations.

The present experiment aims at testing the structural superiority hypothesis in a task preserving the production paradigm's ecological benefit regarding the retrieval of source situations from the participants' own experience (in line with Blanchette & Dunbar, 2000 and Trench and Minervino, 2015) while isolating the influence of surface and structural similarities by comparing the retrieval of superficially dissimilar analogs and superficially similar disanalog (in line with Raynal et al., 2017). As superficially similar analogs' retrievals can be both explained by a surface similarity superiority or a structural similarity superiority account for retrieval, they will not be considered to answer our main question of interest. In accordance with the structural superiority hypothesis, we predicted that situations

showing structural but no surface similarity will be predominantly retrieved compared to situations sharing surface but no structural similarity.

Experiment

Method

Participants

97 participants (78 women and 19 men, $M=24.3$ years, $SD=7.3$ months) took part in the experiment during a university class.

Material

A booklet was presented with, in its first page, the instructions and a target cue presenting a short description of a situation similar to the ones that can be encountered in daily-life. Two sets of the material were built. The first one presented the participants with the following target cue situation: “*I had to go to the Do It Yourself store to buy a lightbulb, but every day I was saying to myself that I would rather go there tomorrow, and it is only some two weeks later that I finally bought it*”. The second one was composed of the following target cue situation: “*I had the idea to answer that I forgot my glasses when the photographer offered me to go to his exhibition. In reality, I had my glasses with me but I had no desire to go there*”. The first and the second pages presented altogether eight plots to be filled with the retrieved memories. Half of the participants received the first set of material and the other half received the second one.

Procedure and experimental design

The task was presented as a memory-recall task. The instructions stated that the participants will have to report a maximum of memories that the target cue situation reminds them of and to report all memories that would come to mind. Also, the instructions stated that the reported situations had to be real memories and not situations invented during the task. Some experiments using an analogy production paradigm have been criticized for inciting participants to create analogs rather than to retrieve real memories (Trench & Minervino, 2015). Indeed, the instruction to generate analogs could become the participant’s priority relatively to the instruction of using real memories. In contrast, the participants were only instructed to recall memories in the free-recall reminding paradigm we used here. Hence, the instruction to retrieve memories could not be overshadowed by the instruction to generate analogs. Participants had 10 minutes to fulfill the task.

Results and discussion

Retrieved situations preserving the relational structure of the target cue were coded as superficially similar analogs when they contained at least one object that was semantically close to one of the target cue’s objects (involving a *light*, a

store or *handiwork* for the *buying a lightbulb* situation, involving *photography*, *glasses* or *cultural activity* for the *refusing to go to an exhibition* situation), and as superficially dissimilar analogs when they did not show any semantic overlap at the objects’ level. Retrieved situations which did not preserve the relational structure (*an activity that should be done now is postponed* for the *buying a lightbulb* situation, *providing an excuse to avoid a situation* for the *refusing to go to an exhibition* situation) were coded as superficially similar disanalogs if at least one object was semantically close to an object of the target cue, and as superficially dissimilar disanalogs when there was no semantic overlap with any objects.

A total of 304 situations were reported by the participants. The mean number of memories reported for each participant was 3.3. Among all retrieved situations, 50.3% were superficially dissimilar analogs, 26.6% were superficially similar disanalogs, 13.2% were superficially similar analogs and 9.9% were superficially dissimilar disanalogs (Figure 1).

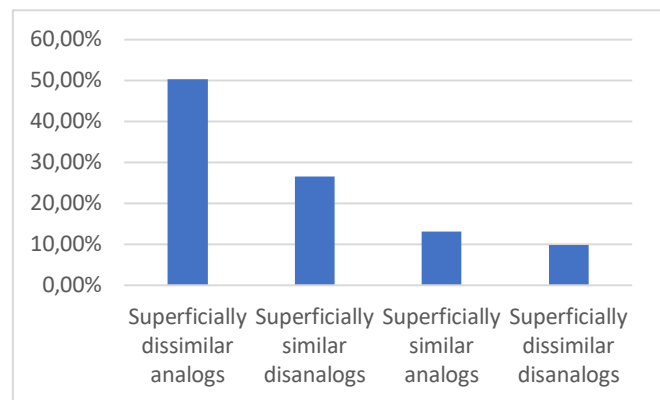


Figure 1: proportion of retrievals for each type of source candidate situations

It could be criticized that the higher number of superficially dissimilar analogs over superficially similar disanalogs is the consequence of participants who retrieved superficially dissimilar analogs reporting more memories and participants who retrieved superficially similar disanalogs reporting less memories. The comparison of the number of participants predominantly retrieving superficially dissimilar analogs over superficially similar disanalogs and vice versa may be a more appropriate measure to assess the structural similarity superiority hypothesis. In this line, analysis revealed that 58.8% (61.2% in the *buying a lightbulb* version and 56.3% in the *refusing to go to an exhibition* version, as can be seen in Figure 2) of the participants retrieved more superficially dissimilar analog than superficially similar disanalog source candidate situations. 24.7% of the participants retrieved more superficially similar disanalog than superficially dissimilar analog source candidate situations (24.5% in the *buying a lightbulb* version and 25% in the *refusing to go to an exhibition* version). A chi square performed on the number of participants who retrieved more superficially dissimilar analog than superficially similar disanalog source candidate

situations compared to participants who retrieved more superficially similar disanalog than superficially dissimilar analog source candidate situations revealed a significant difference ($\chi^2(1, N=80)=13.44, p < .001$).

Results are in accordance with the structural superiority hypothesis in that participants more frequently retrieved preferentially superficially dissimilar analog rather than superficially similar disanalog source candidate situations. It appears that retrievals were more influenced by structural similarity alone than by surface similarity alone. Retrieving

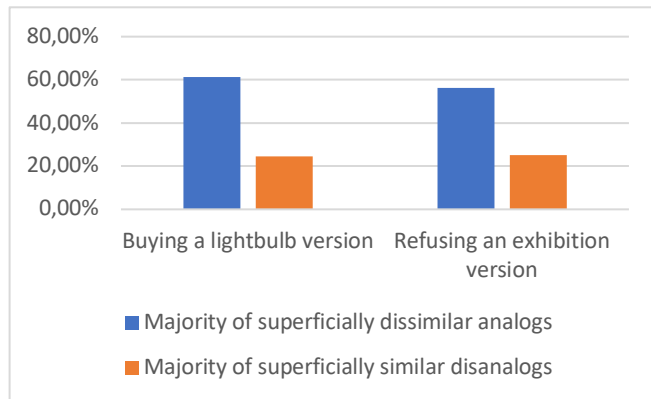


Figure 2 : proportion of participants retrieving more superficially dissimilar analog than superficially similar disanalogs and the inverse

only one superficially dissimilar analog source candidate situation can be considered as an evidence of the encoding of the situations' structure. In this line, analyses were drawn and revealed that 76.3% of the participants retrieved at least one superficially dissimilar source candidate situation, showing an ability to encode situations in an abstract way. It could be

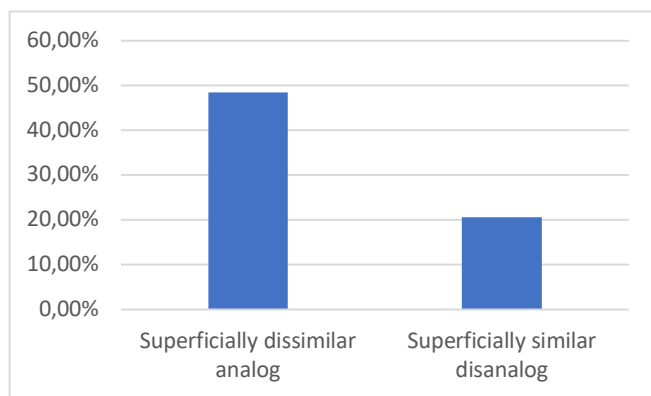


Figure 3: proportion of participants retrieving a superficially dissimilar analog or a superficially similar disanalog for the first reported memory

opposed that a global analysis of the distribution of each type of retrievals could hide a higher proportion of surface similarity-based access for the first memory that is accessed. Indeed, access could be primarily based on surface features

and then be progressively oriented toward structural features of the target cue situation. However, as shown in Figure 3, further analysis demonstrated that the source candidate situations which were recalled in the first place were significantly more frequently superficially dissimilar analog (48.5%) than superficially similar disanalog source candidate situations (20.6%, $\chi^2(1, N=66)=10.88, p < .001$). These data suggest an early focus on the structural features of the target cue.

Conclusions

Using a free-recall reminding paradigm, we investigated the type of retrieval elicited by familiar situations without instructing participants to draw analogies. Given that both the structural and the surface similarity hypotheses can account for superficially similar analogs' retrievals, we focused on the comparison of the recall of superficially dissimilar analog source candidate situations that can only be driven by structural similarity and superficially similar analog source candidate situations that can only be elicited by surface similarity. As predicted by the structural superiority hypothesis, retrievals of superficially dissimilar source candidate situations were preponderant, while retrievals of superficially similar disanalog source candidate situations were only marginal, failing to support the surface similarity superiority hypothesis.

The difference is striking when comparing the number of participants retrieving the superficially dissimilar analog source candidate situation in Trench and Minervino's (2015) second experiment (16.5%) and the number of participants retrieving a (at least one) superficially dissimilar analog source candidate situation in our study (76.3%). A possible explanation deals with the fact that only the retrieval of one superficially dissimilar source candidate situation was considered in their study (e.g. *having consumed so much of a new food with the consequence of becoming disgusted of it* or *of having played a video game so much with the consequence of getting fed up with it*), whereas we coded all superficially dissimilar source candidate situations that were retrieved by the participants. Indeed, superficially dissimilar analog source candidate retrievals would have seemed much less frequent in our study if we had only coded one type of superficially dissimilar analog source candidate situation (e.g. *an-mail that should be sent now is postponed* for the *buying a lightbulb* target cue situation).

Although the present study's major aim was to determine whether structural or surface similarity is preponderant in retrieval, our results can also shed light on the question of the superiority of superficially similar versus dissimilar analog source candidate situations' retrievals (Blanchette & Dunbar, 2000; Trench & Minervino, 2015). At first sight, it appears that our results replicate the preponderance of superficially dissimilar over superficially similar analog source candidate situations' retrievals observed in Blanchette and Dunbar (2000), in contrast with Trench and Minervino's (2015) results. Indeed, it appears that the encoding is abstract in a

way that structural similarity on its own can be used to retrieve a situation. If the data demonstrate that structural similarity may be the main factor influencing access, it does not preclude that surface similarity plays an important additional role. Notably, research has suggested that superficially similar analogs are preponderant when driving predictions or identifying problems whereas superficially dissimilar analogs are mainly used with explanatory goals (Dunbar, 1997; Christensen & Schunn, 2007; Kretz & Krawczyk, 2014). The preference for a superficially similar or dissimilar analog is affected by the goal one is pursuing. Hence, more studies are needed to inform the type of contexts influencing the preference for a superficially similar or dissimilar analog instead of drawing an absolute supremacy between the two types of analogies.

The failure to rely on structural similarity in retrieval, which is referred as the “retrieval gap” (Holyoak, 2012), would confine the possibility to draw analogies to contexts in which two analog situations are presented jointly, allowing the mapping process to occur. On the contrary, the demonstration of a structural similarity-based retrieval suggests that analogs can be accessed from long-term memory, permitting analogies to occur more frequently than it was supposed to under the surface similarity account for retrieval.

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