Structural similarity superiority in a free-recall reminding paradigm

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Abstract

In this study, we test the possibility that real-life events induce an abstract category activation in a way that permits structurally-based retrievals. We used a free-recall reminding paradigm where participants had to report any memory that come to mind when faced with a target cue embodying a familiar concept. This method allowed us to consider the retrievals of any analog that shares a meaningful structural similarity in the participants' own eyes. Results revealed that most participants predominantly retrieved Superficially Dissimilar Analogs (SDAs) rather than Superficially Similar Disanalogs (SSDs). Interestingly, retrievals of SDAs were preponderant over retrievals of Superficially Similar Analogs (SSAs). These data suggest that familiar abstract knowledge may have a more important role in promoting abstract encoding and structurally-based retrievals than it was supposed to.

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

Introduction

Some analogies, like the one Rutherford has drawn between the solar system and the atom, are not within anyone's reach. An explanation for the difficulty to find such analogies is that, despite an important structural overlap between the source and the target cue situations (they share similar relations since the sun *attracts* planets *causes* the planets to *revolve around* the sun, just like the nucleus *attracts* electrons *causes* the electrons to *revolve around* the nucleus), they do not share surface/superficial similarity (they involve objects from different semantic domains: *sun* and *planets* in the source, and respectively *nucleus* and *electrons* in the target cue) (Gentner, 1983). Indeed, the absence of surface similarity would make a source situation difficult to access from long term memory since, following Forbus, Ferguson, Lovett & Gentner (2017), "*memory retrieval is strongly influenced by content, and only weakly influenced by relational structure*" (p. 1164).

However, it is possible that some analogies between Superficially Dissimilar Analogs (SDAs) are much more easily generated than the Rutherford one. For instance, 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? Contrary to the structural similarity lying between the solar system and the atom, a concept that is familiar for most people may allow one to encode a common *procrastination* structure underlying those daily-life situations. In this paper, we propose that situations referring to familiar abstract concepts can elicit structurally-based retrievals.

The relational gap

Numerous studies have addressed the question of analogical retrieval within a problem-solving context, where a source problem is provided to the participant with its solution before an analog target problem has to be solved. Participants seldom spontaneously notice the structural similarity lying between two SDA problems (Gick & Holyoak, 1980). Indeed, the encoding of the problems would not be sufficiently focused on abstract features to permit a structurally-based access (Gick & Holyoak, 1983). This explanation is supported by studies showing that performance increases when the problems are Superficially Similar Analogs (SSAs) (Keane, 1987; Ross, 1987).

This conclusion is also supported by story-recall studies, where source stories are provided before target stories sharing surface and/or structural similarity are presented. These studies have shown that *analogy-matches* (SDA) are seldom retrieved, whereas *literal matches* (SSA) are retrieved much more often (Gentner, Ratterman & Forbus, 1993). The failure of abstract encoding is even better illustrated by the result indicating that *mere appearance matches* (Superficially Similar Disanalog - SSD) target cues are more efficient than SDAs in driving retrieval of a source story. The role of structural similarity in retrieval was questioned since SSAs were not significantly better retrieved than SSDs and SDAs were not significantly better retrieved than Superficially Dissimilar Disanalogs (SDDs).

Trench and Minervino (2015) came to similar findings with a production paradigm (Blanchette & Dunbar, 2000) where they controlled the availability of a SSA or a SDA in

memory. Participants had to generate analogies with their own experiences to dissuade someone from adopting a given behavior (e.g. *someone who enjoys passion fruit who intends to incorporate it into cheesecakes, toppings and daiquiri*). In line with previous results, they showed that analogical retrievals were oriented toward SSA (e.g. *having consumed so much of a new food with the consequence of becoming disgusted of it*), with rare occurrence of SDA retrievals (e.g. *having played a video game so much with the consequence of getting fed up with it*). The contrast between the relative ease to detect structural similarity when asked to map two SDAs (Gentner *et al.*, 1993) and the difficulty to base retrieval upon this structural similarity has been named a "relational gap" (Holyoak, 2012).

Abstract concepts to fill the relational gap

Gentner, Loewenstein & Thompson (2003) have suggested that the surface dominance in retrieval is a consequence of the encoding that would be mainly focused on surface features. However, there is some empirical evidence that the encoding is not superficial *per se*, but depends on the knowledge one has about the situations. Indeed, studies on expert populations suggest that familiar concepts promote an abstract encoding that can fill the relational gap: experts are able to generate distant analogies when pursuing specific goals (Christensen & Schunn, 2007; Kretz & Krawzyk, 2014). Also, they are better able than novices to transfer solution based on structural similarity across SDA problems (Novick, 1988). Moreover, the development of adequate abstract concepts has been identified as a critical factor allowing experts to reach the abstract structure of problems (Chi, Slotta & Joram, 1992).

It has been argued that simple and local concepts could explain why lay participants would mainly base their retrieval on surface features (Loewenstein, 2017). In this view, the extraction of an abstract schema could be elicited by specific experimental settings. Analogical encoding, by which a participant is instructed to compare two analog source situations (Gick & Holyoak, 1983; Gentner et al., 2003) or two target cue situations (Gentner, Loewenstein, Thompson & Forbus, 2009; Dekel, Burns & Goldwater, 2017) before the retrieval phase would be a way to induce the extraction of a schema highlighting the abstract features of the analog situations.

However, abstract concepts can be activated without a specific assistance during the encoding of the situations: Bassok, Wu and Olseth (1995) have shown that novice participants became able to transfer a solution between combinatorial problems when they both could be interpreted through a familiar "get" concept, that is to say, when both involved objects distributed to humans rather than the reverse. Further, the activation of relational knowledge seems to be an automatic process that is elicited while perceiving familiar objects (Bassok, Pedigo & Oskarson, 2008) and Popov, Hristova and Anders (2017) showed that familiar objects' relations are spontaneously encoded with the consequence that participants falsely recognize two objects words (*e.g. artery – blood*) when they had been previously presented with two other objects usually sharing a similar relation (*e.g. pipe – water*). Further, it has been demonstrated that pictures of real-world situations activate abstract concepts in a way that primes a lexical decision on these concepts' labels (McRae, Nedjadrasul, Pau, Pui-Hei Lo & King, 2018). The view that abstract knowledge is activated in familiar daily-life situations is also supported by Schank (1982), showing that similar high-level structures are involved in situations occurring in different contexts (*e.g. visit to a doctor* and *visit to an accountant*). According to Hofstadter and Sander (2013), the abstract encoding of a familiar analog situation can give rise to a *conceptual skeleton* that can be reactivated in new analog situations. This conceptual skeleton becomes stored in LTM in the form of a category of situations referring to more and more abstract features, as new analog situations are encountered and confirm the structural core of this new category. As they become familiar concepts, these categories of situations should be spontaneously activated during the encoding of new analog situations, thus promoting an abstract encoding that can support analogical retrieval. However, Jamrozik and Gentner (2013) have shown that participants that were presented with SSD and SDA stories corresponding to such category (called *schema category*) manifested the surface bias, unless the label of the category was explicitly provided with the SDAs (*e.g.* "this is an example of *reciprocity"*). Hence, the category would not be spontaneously activated during the encoding of the situations in a way that could elicit structurally-based retrievals.

Numerous authors have highlighted that story-recall tasks do not invite participants to process a deep encoding of the stimuli (Hammond, Seifert & Gray, 1991; Blanchette & Dunbar, 2000; Hofstadter & Sander, 2013). Indeed, it is possible that text-stories make the participants less involved in the situations than the events that he or she encounters in daily-life, which bear more personal significance. This shallow processing conditions may have prevented participants from encoding the situations through their respective category. This may have oriented participants towards the retrieval of SSDs rather than towards SDAs. Also, Gentner (2010) noted that relations may not be as likely as objects to be encoded in a uniform way. The author suggests that this may be one of the reasons why providing a similar label to relationally similar situations, by encouraging their uniform encoding, promotes relational retrievals. We propose that another way of opening the door for relational retrieval may be to leave to the participants the possibility to retrieve any source analog that shares a meaningful structural similarity with the target cue in the participants' own eyes. In the present experiment, we used a free-recall reminding paradigm where participants faced with a target cue situation which corresponded to a category had to report any memories that came to mind. Our aim was to assess the structural superiority hypothesis according to which structural similarity surpasses surface similarity in driving the retrieval of events referring to familiar knowledge. As SSAs contain both structural and surface similarity, their retrievals can be

both explained by the structural superiority and the surface superiority accounts for analogical retrieval. Hence, we focused on SDA and SDD retrievals, and predicted that source situations sharing structure but no surface would be predominantly retrieved over situations sharing surface but no structure.

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 that could be interpreted through a familiar category. Two target cue situations were constructed, one referring to *procrastination*, and the other referring to *excuse,* although these labels were not provided to the participants (*c.f.* Table 1). The first and the second pages presented altogether eight plots to be filled with the retrieved memories. Half of the participants received only the *procrastination* target cue and the other half received only the *excuse* target cue.

Table 1 : The two target cue situations (translated from French)

Procrastination
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 I only bought it some two weeks later
Excuse
I had the idea to answer that I forgot my glasses when the photographer offered me to go to his exhibition. The reality is that I had my glasses with me but I did not want to go there.

Procedure and experimental design

Contrary to most previous experiments investigating the retrieval of events from the participants' own experience (Blanchette & Dunbar, 2000; Trench & Minervino, 2015), we did not ask participants to generate analogies. Two reasons motivated this choice. First, the instruction to generate analogies is adequate to assess the role of surface similarity in analogical retrieval, but it may not fit our aim to compare the role of surface similarity to the one of structural similarity in retrieval. Indeed, participants prompted to generate analogies are incited to retrieve structurally similar situations (SDAs or SSAs rather than SSDs). Second, the explicit goal to seek for analog situations may invite participants to create analogs rather than to retrieve real memories (Trench & Minervino, 2015). Accordingly, 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. Hence, no goal to generate analogies could overshadow the instruction to recall real memories. Additionally, the instructions explicitly stated that the reported situations had to be real memories and not situations invented during the task.

Results and discussion

Each memory that was retrieved was coded following Gentner et al.'s coding scheme (1993; 2009; Jamrozik & Gentner, 2013), according to the presence or absence of surface and the presence or absence of structural similarity (as illustrated with the example provided in Table 2). A SSA shares both structural and surface similarity, a SSD shares only surface similarity, a SDA shares only structural similarity, and SDD does not share any similarity. Retrievals were coded as preserving the *procrastination* structure when they contained each of the three following basic ingredients: (1) an activity that should be done now (2) is deliberately (3) postponed. Similarly, the *excuse* structure was decomposed in three segments involving (1) pretending (2) an impediment (3) in order to avoid a given situation. Source situations containing only two or less of these segments were coded as a SSD or a SDD according to whether they share surface similarity or not. The surface similarity was attributed to source situations containing at least one object that was either identic or semantically related to one of the target cue's objects. Regarding the *procrastination* target cue, each source situation referring to a *store*, *handiwork*, or a *light* were coded as superficially similar. Retrievals were coded as preserving the surface of the *excuse* target cue situation when they involved a *cultural activity*, a *photographer*, or *glasses* (or any *visual disabling*). The two first authors independently coded each reported memory as a SDA, a SSA, a SSD or a SDD.

Four participants returned blank protocols and were excluded from the analyses. A total of 312 situations were reported by the participants. The mean number of memories reported for each participant was 3.4. The two independent raters agreed on 89.4% of the 312 situations. Disagreements were resolved through discussion. Among all retrieved situations, 46.1% were SDAs, 27.6% were SSDs, 11.9% were SSAs and 14.4% were SDDs (*c.f.* Figure 1).

Further analysis was drawn to assert that the preponderance of SDAs over SSDs in the total number of retrievals from all participants taken together is not a consequence of the fact that participants retrieving SDAs tended to generate more memories than other participants. Indeed, the comparison of the number of participants predominantly retrieving SDAs over SSDs and vice versa

may be a more appropriate measure to assess the structural similarity superiority.

Table 2 : Examples of situations reported by the participants presented with the *procrastination* target cue (translated from French)

Superficially Dissimilar Analog (SDA)
It reminds me of the situation in which I was a few months ago, when I had to register in the University and ask for a scholarship. I was so lazy that I postponed this many time and I finally did it in October.
Superficially Similar Analog (SSA)
I had to go to a shop to buy a gift for a friend of mine, but I first said to myself that I could rather go there later, at the end of the month, and I finally took six months to go there.
Superficially Similar Disanalog (SSD)
I went to the Do It Yourself store some months ago with my father to spend some time with him, but I finally left him when my girlfriend called me.
Superficially Dissimilar Disanalog (SDD)
My mother wanted me to tidy my room, but I did not want to do it, so she finally threw my stuffs in the trash.

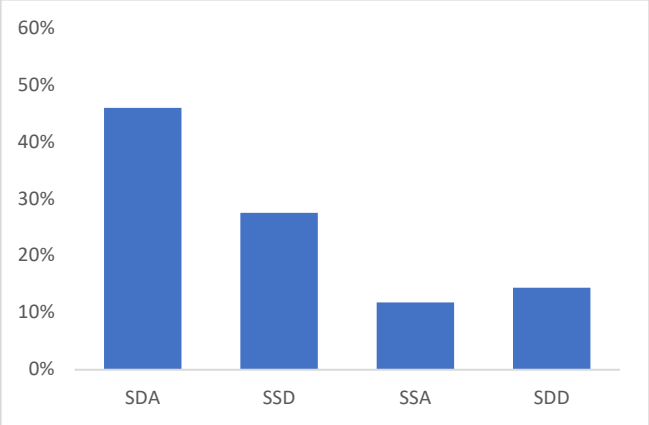

Figure 1: proportion of retrievals of each type of source

In this line, analysis revealed that 58.1% of the participants retrieved more SDAs than SSDs (60% for the *excuse* target cue and 56.3% for the *procrastination* target cue, as can be seen in Figure 2). 30.1% of the participants retrieved more SSDs than SDAs (31.1% for the *procrastination* target cue and 29.2% for the *excuse* target cue). A chi square performed on the number of participants who retrieved more SDAs than SSDs compared to the number of participants who retrieved more SSDs than SDAs revealed a significant difference ($X2$ (1, N=81)=8.26, $p < .05$).

Figure 2: proportion of participants retrieving more SDAs than SSDs or the inverse

Results are in accordance with the structural superiority hypothesis in that participants more frequently retrieved more SDAs than SSDs rather than the inverse. It reveals that retrievals are more influenced by structural than surface similarity. We sought to assess the proportion of participants who, as far as their retrievals suggest it, processed an abstract encoding of the situations. We considered that participants retrieving at least one SDA may have processed such abstract encoding. Analyses revealed that 74.2% of the participants retrieved at least one SDA, suggesting that a great majority of the participants did spontaneously encode the situations according to their structural features.

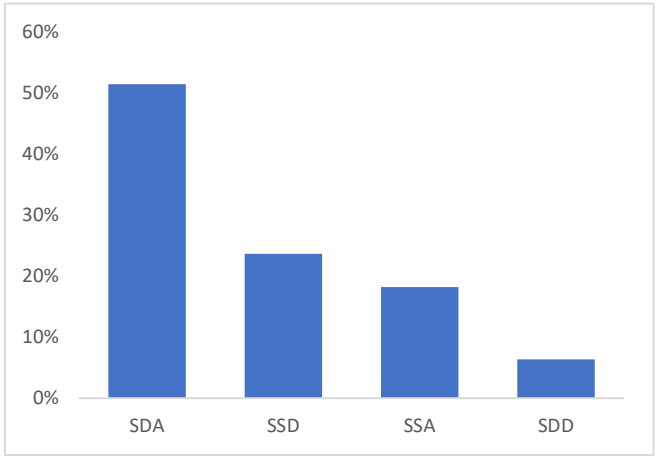

Figure 3: proportion of first retrievals for each type of source

We were also interested in the first retrieval that was reported by the participants. Indeed, this analysis could reveal whether participants directly encoded and use the structure of the target cue situation to drive the retrieval a SDA, or whether they were more incline to be focused at first on

surface features, leading to superficially-based retrievals, and then progressively started to consider structure features. Among all the first retrievals of the participants, 51.6% were a SDA, 23.7% were a SSD, 18.3% were a SSA and 6.4% were a SDD (*c.f.* Figure 3). A chi square performed on the number of first retrievals of a SDA compared to the number of first retrievals of a SSD revealed a significant difference (X^2 (1, N = 69) = 9.66, $p < .01$). These data suggest a direct encoding of the structure.

Conclusions

Prior research has emphasized the superior role of surface similarity over structural similarity in driving retrieval (Gick & Holyoak, 1983; Gentner et al., 1993; Trench & Minervino, 2015). Following studies showing the encoding of structural features in expert populations as well as the activation of familiar concepts from daily-life when lay participants encode familiar situations, we assessed whether the surface dominance applies in familiar situations referring to an abstract category, which our every day-life abounds with. A free-recall reminding paradigm was adopted where participants were allowed to recall any situation from their own experience, so that the retrieval of any source analog that the participant had encoded through a similar category could be considered. Results demonstrated a preponderance of retrievals of SDAs over SSDs, suggesting that the activation of an abstract category can fill the relational gap. The difference between our results and those from Jamrozik and Gentner (2013) when no category label was presented highlights the importance of considering the retrieval of sources from one's own experience rather than from text-stories encoded in an experimental context.

Another difference between our results and previous findings deals with the proportion of SDAs versus SSAs that were retrieved. Trench and Minervino (2015) indicated that 16.5% of the SDAs against 45% of the SSAs were retrieved when faced with a familiar target cue situation (e.g. *someone who enjoys passion fruit who intends to incorporate it into cheesecakes, toppings and daiquiri*). In contrast, our results showed a reversed pattern with 46.1% of the total retrievals leading to SDAs and only 11.9% guiding to SSAs. It is possible that when dealing with a familiar situation such as eating too much of a pleasant food, the goal to use analog personal experiences to convince someone orients participants towards the most similar experience (*i.e.* not only at the level of a highly abstracted structure), bearing the higher predictive power. Another possibility is that the encoding is made even more abstract when the extraction of a schema can be supported by the activation of a stored category. While the structural encoding of familiar situations such as the ones investigated in Trench and Minervino (2015) may still contain some surface features, the structural encoding through an abstract category activation may induce a direct encoding of the situations' abstract structure in a way that analogical retrieval becomes more prompted to reach source analogs in various semantic domains.

The contrast between the superiority of SDA retrievals when the structure can be captured through an established category and the superiority of SSA retrievals in the absence of such category could make one think of a switch from a surface superiority to a structural superiority following the presence or not of a corresponding abstract category. Indeed, studies showing the superiority of SSA over SDA retrievals have generally concluded that surface similarity was the predominant factor leading to such retrievals. In this line, Trench and Minervino (2015) suggest that "the proficient analogizer begins by including surface information about the target in the working memory probe that will be used for retrieval (…)" (p. 23), consistent with Loewenstein's (2017) proposal that while making an analogy with a superficially similar analog, "we will probably be focused at first on corresponding surface features (…) "(p. 8446). However, the foundation of the surface dominance proposal can be questioned when considering that SSA may not have only more surface similarity than the SDA, but may also share a higher overlap at the level of abstract similarity (*e.g.* two episodes where someone intends to abuse of a food he or she enjoys share abstract features such as the fact the characters may have a sweet tooth or that he or she risks to put on weight or to get sick) that an analog from another domain may not preserve. Although the higher rate of SSDs over SDAs reported in Gentner et al. (1993) could be considered as an evidence that surface similarity overpowers structural similarity in retrieval, it can be noted that the stories sharing a mere-appearance match do not only share surface, but also share a substantial part of their structure. Raynal, Clément and Sander (2017) provided evidence showing that when surface and structural similarity are dissociated between a target cue and different source stories, structural similarity predominantly drives access over surface similarity.

Our study provides new findings inciting a unifying view of analogy and categorization processes (Hofstadter & Sander, 2013). Prior research has shown that analogies are at the heart of the categorization process (Ramcar & Pain, 1992). Analogies give rise to abstract schemas (Gick & Holyoak, 1983; Gentner et al., 2003; 2009) and abstract categories (Christie & Gentner, 2010; Hofstadter & Sander, 2013). Namely, it has been suggested that some particular types of categories, being characterized by relational features (relational categories like *robbery* or *thief*) as opposed to entity categories (*e.g. vehicule.*), would be learned through analogies (Gentner & Kurtz, 2005). Considering that most categories possess relational features (e.g. *vehicules* transports people from a location to another), one can wonder to which extent all forms of categories progress through analogies. Reciprocally, our results suggest that the activation of abstract categories supports analogical retrievals. Further studies are needed to investigate the impact of familiar abstract concepts on the encoding as well as on the subsequent analogical retrievals within or outside a target cue's semantic domain.

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