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How Analogies are Generated: The Roles of Structural and Superficial Similarity

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Abstract

Laboratory studies of analogical reasoning have shown that subjects are mostly influenced by superficial similarity in the retrieval of source analogs. However, real-world investigations have demonstrated that people generate analogies based on deep structural features. We conducted three studies to determine why laboratory and real-world studies have yielded different results. In the first two studies, we used a “production paradigm” in which subjects were asked to generate sources for a given target. Results show the majority of analogies generated displayed low levels of superficial similarity with the target problem. Moreover, most analogies were based on complex underlying structures. The third study used a “reception paradigm” methodology. Participants had to retrieve predetermined sources instead of generating their own. In this case, retrieval was largely constrained by surface similarity. We conclude that people can use structural relations when given an appropriate task and that previous research on analogy has underestimated this ability.

How Analogies are Generated: The Roles of Structural and Superficial Similarity

An important feature of human cognition is the ability of people to use analogical reasoning (Holyoak & Thagard, 1997). Analogy involves using knowledge from one relatively well-known domain (the source) and applying it to another domain (the target) on which the reasoner is working (Spellman & Holyoak, 1996; Clement & Gentner, 1991). Analogy involves two levels of relations between the representations of the source and target. Superficial similarity refers to the resemblance between the objects in the source and target and their properties (Keane, Ledgeway, & Duff, 1994). Structural similarity refers to the resemblance in the underlying systems of relations between the elements of the sources and the elements of the target. Structural similarity exists if the relations holding between the objects in the source are similar to the relations between the objects in the target, independently of the similarity between the objects themselves (Forbus, Gentner & Law, 1994). Many authors have argued that structural similarity is the crucial defining feature of analogy (Gentner & Markman, 1997).

Over the past 20 years, many experiments have been conducted to investigate the roles of superficial and structural similarity in analogical reasoning. These experiments have demonstrated that the two types of similarity constrain analogical reasoning in different ways. Superficial similarity has been found to be the main determinant of source access and retrieval while structural similarity influences mostly the mapping and evaluation stages (Catrambone 1997; Gentner, Ratterman, and Forbus, 1993; Gick & Holyoak, 1980; Keane, 1987).

Most of the research on analogy has shown that subjects in laboratory experiments tend to rely on superficial features when accessing source analogs. For example, Gentner, Ratterman, and Forbus (1993), using a story-memory task, examined the contributions of the different types of similarity in retrieval. In their experiment, subjects were presented with a set of stories and were later asked to mention any reminding they experienced when presented with similar stories. Three types of correspondence between pairs of stories were manipulated: similarity between the objects in the source and target, similarity in the first-order relations (relations between the objects) in the source and target, and similarity in higher-order relational structure (relations between relations). Their results show that surface similarity and similarity in first-order relations facilitate retrieval. Superficially similar pairs of stories, those sharing object attributes and first-order relations, were more frequently accessed than those with only first and higher-order relations in common. Catrambone (1997), using a similar paradigm but manipulating the degree to which stories shared superficial and structural features also demonstrated a strong effect of superficial similarity on the retrieval of sources. His results also show that similarity in first-order relational matches increases the frequency of source access.

The facilitating effect of surface similarity on retrieval has also been demonstrated in the context of problem-solving tasks. Gick and Holyoak (1980) used Dunker's radiation problem¹ to investigate analogical problem solving. The subjects were presented with a source story suggesting a correct convergence solution before being given the problem-solving task. The results reveal that the vast majority of subjects failed to notice the relevance of the source story when attempting to solve the target problem. Only 20 percent of the subjects retrieved the source analog spontaneously. When the surface features of the source were more similar to those of the target problem, 90 percent of the subjects spontaneously retrieved it to produce the convergence solution (Holyoak & Thagard, 1995). Keane (1987) also looked at the effect of surface similarity in the context of a problem-solving task. In his experiment, surface similarity and structural similarity were manipulated. Keane's results indicate that source analogs sharing only structural similarity with the target are seldom retrieved (12%) when compared to analogs with common structural and surface

features (88%). Overall, these types of results indicate that people often fail to retrieve a relevant source analog in memory when it lacks surface similarity with the target problem.

Some researchers have, however, found some effects of structural similarity in retrieval of analogical sources (Catrambone, 1997; Gentner et al., 1993; Wharton, Holyoak, Downing, Lange, Wickens, & Melz, 1994). This role seems to be limited, mostly complementary to the role of surface similarity. In certain cases, for equal levels of superficial similarity, greater structural similarity can facilitate retrieval.

Overall, empirical findings from memory and problem solving tasks indicate that surface similarity is the most important factor in determining retrieval of a source. However research on the use of real-world analogy has found that the analogies that people use tend to be based on deep structural features rather than superficial features. For example, Dunbar (1995; 1997) has investigated the use of analogy at weekly laboratory meetings in molecular biology laboratories. He has found that over 50% of the analogies that the scientists generate are based on deep structural features rather than superficial features. Similarly, Blanchette and Dunbar (1997) have found that over 60% of the analogies used in newspapers during a political debate in Canada showed low levels of superficial similarity between the source and target.

Why is it that subjects in standard psychology experiments infrequently use structural features in their retrieval of source analogs, whereas analogies based on structure are frequently used in real-world contexts? One possibility is that research on analogy has tended to use what we call a "reception paradigm"² in which subjects are given source and target analogs and must see the relationship between them, rather than the subjects generating their own analogies. Using the reception paradigm, the experimental set-up may constrain the search for structural relations and provide a picture of analogical reasoning that underestimates subjects' abilities to use deep structural features in the retrieval of source analogs. In real world contexts, people generate their own analogies. This suggests a different approach to investigating analogy, rather than using a reception paradigm, in which subjects are given sources and targets, analogy can be investigated using a "production paradigm" in which subjects are given a target problem and are asked to generate source analogs. In addition to investigating why people in real-world contexts can generate analogies based on underlying structure, the use of a production paradigm makes it possible to investigate the types of features that people attend to when they generate analogies and identify what types of search strategies the subjects use.

Overview of Studies

We designed a hypothetical situation in which subjects had to produce persuasive political analogies. The topic on which subjects were asked to generate analogies was the debate over achieving a zero deficit. Zero deficit is the term used to describe many governments' goal of eliminating yearly differences between earnings and expenses that lead to national debts. We chose this issue because of its pervasiveness and importance. Most governments in Western societies face substantial problems with public finances. Particularly, in Canada, where this study was conducted, the provincial and federal governments are all concerned by this problem and have dealt or are dealing with the issue using different approaches. While most people agree that public debts are an important problem, the debate resides mainly in how urgent, or how important the attainment of a zero deficit should be. Simplifying the debate greatly, advocates of the Pro-zero deficit side argue that reducing the deficit must be the most urgent priority, warranting drastic cuts in government spending. The Anti-zero deficit side, while not opposed to the reduction of the deficit, most frequently argues in favor of the preservation of social programs.

The goal of Study 1 was twofold. The first was to determine whether the use of a production paradigm would make it possible for subjects to retrieve source analogs based on structural features rather than superficial features. If the use of a reception paradigm is the reason why subjects in standard psychology experiments on analogy do not show the same ability as do subjects in real-world contexts to use structural features in the retrieval of source, then we would expect subjects in a laboratory task using a production paradigm to

generate analogies based on structural similarity. The subjects were therefore asked to generate analogies on a given target problem: the zero-deficit issue.

A coding scheme was developed in order to assess the influence of superficial and structural constraints on the production of analogies in this task. Because superficial similarity is defined as the similarity between the objects and their properties in the source and target (Keane et al., 1994), we categorized the different sources generated according to their semantic domain of origin. Sources from the same categories share similarities in features and these categories could in turn be evaluated on their level of similarity with the target problem. The underlying structures of each of the analogies was also assessed by identifying both the first-order relational statements (relations between objects) and the higher-order relational structures (relations between relations) common to both the source and target (Gentner et al., 1993).

The second goal of the experiment was to further understand the features of the problem that are used by people to generate and evaluate analogies. In this experiment we wanted the subjects to give as much information as possible about the ways that they retrieve and evaluate source analogs. Our previous research has shown that groups of scientists have little difficulty in generating structural analogs and that discussion of the features of the sources and targets by members of the group provided insights into the mechanisms that the scientists used in generating analogies (Dunbar, 1995; 1997). Similarly, we used groups of subjects to generate analogies. By using groups, we expected participants to discuss features of the sources and targets that were relevant to them. Furthermore, we could get the subjects to evaluate their analogies and gain further information on the dimensions that are important in the evaluation of political analogies.

Study 1 Method

Participants

Forty-nine undergraduate students majoring in different disciplines participated in the study. They were recruited through sign-up sheets posted in the department of psychology at McGill University and through the subject pool of the department of psychology, in which case they received credit for their participation in the study. Participants were compensated for their time.

Twelve groups were run in this study, four groups of three participants, three groups of four participants and five groups of five.

Task and Procedure

A brief introduction to the zero deficit issue was first read to the participants. This short text defined terms like deficit and debt, succinctly described the problem of large public deficits, gave an estimate of the proportions of the problem for Canada and its provinces, and presented two basic viewpoints opposing one another: pro-zero deficit and anti-zero deficit (see Appendix A). After the participants had been introduced to the issue, they were read the instructions (see Appendix B). There were two conditions, Pro-zero deficit and Anti-zero deficit. In both conditions, participants were asked to pretend to be consultants that had been hired by either the National Association of Community Groups (NACG, in the Anti zero deficit condition) or the National Association of Responsible Citizens (NARC, in the Pro zero deficit condition). In both cases, the group was described as a national coalition currently preparing a campaign to sensitize both the government and citizens. Participants were told that this group is aware that analogies are often used in politics to either explain things or convince people to change their opinion. The analogy between Saddam Hussein and Hitler used by President Bush during the Persian Gulf crisis (see Spellman & Holyoak, 1992), was given as an example. Participants were then instructed that their employers had hired them to generate analogies that could be used in their campaign to convince people to adopt their viewpoint. In the Anti-zero deficit viewpoint, the basic position of the fictitious NACG was the following: The reduction of the deficit is an important goal but it should not be pursued at any cost, especially if it implies

eliminating social programs, health, education and support for the needy. In the Pro-zero deficit viewpoint, the basic position of the NARC was presented as: The deficit problem should be the number one priority. Given the state of the economy, governments do not have a choice, spending has to be drastically reduced and citizens have to make sacrifices.

After reading the instructions, the experimenter asked if the participants had any questions and then left the group to do the task, leaving a written copy of the instructions and of the introductory text. Participants were videotaped and audio taped during the task. The groups were allowed twenty minutes to produce as many analogies as possible, working as a group. They were asked to write down any analogy that came to mind regardless of their opinion on the quality of the analogy. After completing the task, participants were asked to select the two best analogies.

Data Analysis

The analogies produced by the subjects were first analyzed by listing all elements explicitly stated in the source and all elements explicitly stated in the target. Information on explicit links established by the subject between elements in the source and in the target was also used to complete the description of each analogy. Codings were based on information from both the verbal descriptions of the analogies made by the participants during the task and the written descriptions also produced during the task.

Coding Scheme

The analogies generated by the subjects were coded along different dimensions reflecting the use of superficial and structural features: semantic category of source, range, and underlying structure. In addition, the analogies were also coded for the degree of elaboration and explicitness.

Semantic category of source. The source analogs were classified into different semantic categories. The set of source categories used was not imposed on the data but rather semantically similar sources were grouped together. A minimum number of five sources had to be grouped together in order to create a source category. Sources not corresponding to any of the categories were classified in a category labeled "other".

Range. Sources were also coded on their Range, defined as the degree of semantic similarity between the source and the target. Range was created to provide a global estimate of the degree of superficial similarity between the source and the target. In this case, the target always being the deficit problem, analogies coded as within-domain were analogies for which the source was taken from the domains of either politics, economics, or personal finances. Sources from these three domains have a high degree of superficial similarity with the target problem. Analogies with sources from any other domain (see Table 1) were coded as other-domain analogies.

Underlying structure. The underlying structures of the analogies were determined. For each analogy, the relational structure common to both the source and target was identified. Because many of these relational structures were identical or highly similar (within each condition, Pro-zero deficit and Anti-zero deficit), they were also grouped into similar structure categories following the same procedure as for the semantic categories, again with a criterion of five as a minimum for establishing a category (see Table 4). Analogies using relational structures that didn't correspond to any of the major categories identified through the grouping process were put in the category "other".

Number of elements in source and number of elements in target. To provide an estimate of the degree of elaboration of the analogies, the number of elements explicitly stated in the source and the number of elements explicitly stated in the target were counted. This measure is designed to provide a partial indication of the structural overlap between source and target.

Explicitness of the mapping. Because the analogies varied widely on how explicit the relations between elements in the source and target were, a coding dimension regarding the explicitness of the mapping was added. Analogies were coded as totally explicit if all the elements stated in the source had an explicit counterpart in the target. Totally implicit analogies were analogies for which no elements of the target were mentioned, keeping the

correspondence to the target problem totally implicit. Analogies in which some of the source elements were explicitly linked to elements from the target but others were not were coded as partially explicit.

Production measures. Because of the nature of the task, three different ways of computing the number of analogies produced by each participant were used. A first measure was the number of analogies initiated by a participant. A second production measure, total number of analogies, included both the number of analogies a participant initiated and the number of analogies the participant did not initiate but in which she participated by adding a mapping or an element. The total number of analogies produced by each group was also recorded.

Results

Production of Analogies

A total of 138 analogies were produced by the subjects. On average, participants initiated 2.82 ($SD = 1.74$) analogies and participated in 2.82 ($SD = 2.29$) additional analogies for a total average production of 5.63 ($SD = 3.0$) analogies per subject. The average number of analogies produced by a group was 11.50 ($SD = 4.15$).

Semantic Category of Source

Other-domain analogies constituted 66.67% ($n = 92$) of the total number of analogies produced, while within-domain analogies represented 33.3% ($n = 46$). Nine semantic source categories were obtained. These results and the corresponding frequencies for each category are presented in Table 1, as well as examples from each of the categories. The source categories used most often were economics/politics ($n = 28$, 20.3%), natural resources/disasters ($n = 19$, 13.8%) and personal finances ($n = 18$, 13.0%). Sources in the "other" category represented 16.7% ($n = 23$) of the total number of analogies coded. This category included sources such as training wheels, hostages or a leaky bucket, drawn from domains which overall, were infrequently used.

Insert Table 1 about here

Underlying Structure of Analogies

Ten different categories of underlying structures were identified through the grouping process, five for each viewpoint (Anti and Pro-zero deficit). These structure categories are presented along with their respective frequencies in Table 2. For each condition, specific first-order relational statements were very prevalent. In the Anti-zero deficit condition, the first-order relational statement most often found was "If cut X, then negative consequence". In this case, the specific objects representing both "X" and "negative consequence" varied in the sources. In the targets, "X" and "negative consequence" typically corresponded to social programs and any consequence of cutting the social programs respectively. In the Pro-zero deficit condition, the first-order relational statement most often found was "If Y not solved, then negative consequences". Again, the objects corresponding to "Y" and "negative consequence" varied in the sources. In the target, "Y" usually corresponded to the debt problem and negative consequences of having a debt were associated. In each condition, these first-order relational statements were typically accompanied by other statements, additional premises, or additional consequences. The way in which the different first-order relational statements were put together constituted the defining feature of each of the different structure categories.

Insert Table 2 about here

Explicitness and Elaboration

A majority of the analogies ($n = 77$, 56%) were partially explicit. Forty-four (32%) analogies were totally implicit, 14 were totally explicit analogies (12%). On average,

analogies contained a greater number of elements explicit in the source ($M = 3.10$, $SD = 1.25$) than in the target ($M = 1.22$, $SD = 1.11$), $t(137) = 14.57$, $p < .001$.

Comparison of Anti and Pro-zero Deficit Conditions

Independent sample t-tests revealed no differences between Anti and Pro-zero deficit conditions on the total number of analogies produced, $t(47) = 1.49$, $p > .05$, and number of analogies initiated, $t(47) = 1.37$, $p > .05$. Analogies from the two conditions also did not differ on range ($X^2(1, N = 138) = .005$, $p > .05$), explicitness of the mapping ($X^2(9, N = 138) = .23$, $p > .05$), number of elements in the source ($t(136) = 1.18$, $p > .05$) and number of elements in the target ($t(136) = .90$, $p > .05$). The only variable on which the Anti and Pro analogies differed was source category ($X^2(9, N = 138) = 18.89$, $p < .05$). Pro-zero deficit analogies used sources from the natural resources/disasters category more frequently and the domain of sayings/expressions was used more frequently by the Anti-zero deficit analogies.

Features Related to Choice of Analogy

A chi square performed on Source category by Choice of best analogy (chosen vs. not-chosen) revealed a significant link between the two variables, $X^2(9, N = 125) = 22.87$, $p < .01$. Specifically, sources from the "personal finances" category were more likely to be chosen as the best ones.

 Insert Figure 1 about here

Structure category was also significantly related to choice of best analogies, $X^2(10, N = 125) = 18.56$, $p < .05$. Analogies with relational structures from the category "others" were chosen proportionally less as best analogies.

Another chi square reveals the explicitness of the mapping (totally explicit, totally implicit, and partially explicit) was not related to the choice of best analogy, $X^2(2, N = 125) = .22$, $p > .05$. While explicitness was not related to the choice of best analogies, elaboration in the source was. A t test was performed to compare analogies chosen as best ones to analogies not-chosen on the number of elements contained in the source. On average, the analogies selected as best contained a greater number of elements in the source $t(123) = 2.03$, $p < .05$. A similar t-test performed on the number of elements in the target showed no similar difference between chosen and not chosen analogies, $t(123) = 1.30$, $p > .05$.

Discussion

The results of this first study are congruent with our hypothesis that a production paradigm would allow subjects to make more use of the structural features in the retrieval of source analogs. The majority of analogies generated by the participants in this study did not exhibit high levels of superficial similarity with the target problem (67%). Participants made use of different types of underlying structures in the generation of analogies. Specific first-order relational statements were used very frequently in each condition. Different combinations of these first-order relational statements produced the different structure categories that were used in the two conditions.

Although the influence of superficial constraints was not as important as could have been expected given laboratory research findings, it did have a noticeable influence on retrieval and evaluation of analogies. Of the nine semantic categories of sources, the two categories exhibiting the greatest superficial similarity with the target deficit problem, economics/politics and personal finances, were the most and third most frequently used categories. Furthermore, subjects' evaluations of analogies seem to have been affected by superficial similarity. Analogies using sources from the "personal finances" category were evaluated more positively than others.

Apart from the semantic source category, the only other feature significantly related to the evaluation of the analogies was the degree of elaboration in the source. Analogies selected as the best ones contained a greater number of elements in the source.

The degree of explicitness of the analogies produced by participants in this study is also interesting. Most of the analogies were partially explicit. The objects in the source were

not systematically related to ones in the target and many of the correspondences between source and target were left implicit. Moreover, the number of elements in the source was greater than the number of elements in the target.

Overall, the generation of analogies in this study appears not to have been highly constrained by superficial similarity. There was great diversity in the analogies generated. The domains from which participants retrieved sources were not limited to domains highly similar to the target problem such as economics, politics and personal finances. Rather, the sources were drawn from domains as varied as natural resources, eating, illness, and domestic tasks. It is possible that the enhanced use of structural properties in the generation of analogies seen in these results is an artifact of using a group task. Groups might exhibit greater use of structural features because participants have different backgrounds. It is also possible that group reasoning leads to an increase in processing capacity which would in turn increase the ability to use structural features in the retrieval of sources. To test this hypothesis, we conducted a second study using the same task but in which participants worked individually.

Study 2 Method

Participants

Twelve undergraduate students participated in the study. They were recruited through sign-up sheets posted in the department of psychology at McGill University. Participants were compensated six dollars for their time.

Task and Procedure

Participants in Study 2 were given the same task and instructions as in Study 1, but worked individually instead of in groups. The procedure used was the same. Participants were read the same introduction before hearing their specific instructions, which again assigned them either to the Anti or Pro-zero deficit condition. They were also asked to come up with as many analogies as possible and to write them down. After twenty minutes, the experimenter came back and asked the participant to select her best two analogies. The only difference in procedure with Study 1 was that the experimenter asked the participant for a brief description of each of the analogies after the task was completed.

Data Analysis

The data were analyzed in exactly the same way as in Study 1. Both the information written down by the participant during the task and the subsequent description of the analogies made to the experimenter after the task were used. The coding of the analogies mirrors the coding in Study 1 (source category, range, structure category, explicitness of the mapping, number of elements explicit in the source and number of elements explicit in the target).

Results

Production of Analogies

A total of 124 analogies were produced. On average, participants produced 10.73 analogies during the task ($SD = 5.71$).

Semantic Category of Source

The majority of analogies produced were other-domain analogies ($n = 100$, 80.6%). The same semantic categories of sources were used as in Study 1. The frequency of use of the different semantic categories can be found in Table 3. The two categories used most frequently were personal finances ($n = 17$, 14%) and illness/medicine ($n = 14$, 11%). Sources in the category "other" constituted 44% ($n = 54$) of the total number of sources generated by the participants.

Insert Table 3 and 4 about here

Underlying Structures

The same ten structure categories identified in Study 1 were also used by participants in this study. The frequency of use of the different structure categories are presented in Table 4.

Elaboration and explicitness

For 52 analogies (42%), the mappings were totally implicit. In 31 analogies (25%), all elements in the source were explicitly linked to elements in the target and as such were coded as totally explicit. The remaining 41 analogies (33%) were partially explicit. Overall, analogies contained a greater number of elements in the source ($M = 2.65$, $SD = 1.41$) than in the target ($M = 1.55$, $SD = 1.44$), $t(123) = 7.73$, $p < .001$.

Comparison between Anti and Pro-zero deficit conditions

A one-way ANOVA on the number of analogies produced as a function of condition shows there was no significant difference between the Pro and Anti-zero deficit conditions, $F(1, 10) = .922$, $p > .05$. Analogies from the two conditions again did not differ on range, explicitness of the mapping and number of elements in the target. As in Study 1, the analogies from the two conditions differed on the source categories used (chi square Source category \times Condition, $\chi^2(9, N = 124) = 20.86$, $p < .05$). In addition, there was also a significant difference on the number of elements contained in the source. A t test revealed that analogies produced in the Pro-zero deficit condition contained on average a greater number of elements in the source than analogies from the Anti-zero deficit condition.

Evaluation of analogies

A chi square on Source category \times Choice of best analogy (chosen vs. not-chosen) indicates the choice of best analogies was not related to the source category of the analogies, $\chi^2(9, N = 124) = 7.07$, $p > .05$. Structure category also was not related to choice of best analogy, $\chi^2(10, N = 124) = 9.01$, $p > .05$.

Another chi square was performed on Explicitness of the mapping \times Choice of best analogy. There was a significant relation between the choice of best analogies and the explicitness of the mapping, $\chi^2(2, N = 124) = 17.87$, $p < .001$. Analogies that were totally implicit were selected less than the analogies that were either partially or totally explicit.

The number of elements in both the source and the target were also consistently related to the evaluation of the analogies. ANOVAS performed on the number of elements in the source and target of chosen and not-chosen analogies reveals analogies chosen as best ones had a greater number of elements explicit in both the source, $F(1, 122) = 17.30$, $p < .001$, and the target, $F(1, 122) = 45.21$, $p < .001$, as can be seen in Figure 2.

 Insert Figure 2 about here

Discussion

The results of Study 2 replicate those of Study 1 and were even more pronounced than those of Study 1. Participants working individually appear to have been even less influenced by superficial similarity than their counterparts working in groups. A great majority (81%) of the analogies produced in this second study were not superficially similar to the target deficit problem. A surprising finding was the proportion of source analogs that could not be classified into any of the semantic source categories (44%). Participants in the individual condition exhibited a greater use of original, not frequently used sources than the groups. In addition, in this individual condition, the subjects' choice of best analogy was not influenced by the semantic category of the source. Sources from the "personal finances" category were not selected more as best analogy than sources from the other categories. Overall, superficial similarity seems to have constrained subjects working individually even less than the subjects working in groups.

The subjects' choice of best analogies was again related to the degree of elaboration in the source. In addition, the degree of elaboration in the target was also related to the choice of best analogies. For both the source and the target, analogies chosen as best ones contained a greater number of elements.

Overall, it appears that the results obtained in the first study were not an artifact of using a group reasoning situation. In group and individual situations, participants are able to generate analogies based on deep structural features. The retrieval of sources was not highly constrained by superficial similarity. We suggest that this is due to the methodology used, a production paradigm. But the difference in methodology is not the only difference between ours and previous study. Another important difference is the type of materials used which, in our studies, differ sharply from anything else used in the literature to date. Real-world political problems are complex and ill-defined. Most studies of analogical retrieval have used short stories or even a set of short sentences (Gentner et al., 1993; Wharton et al., 1994) in which the characters and story line are well defined. Another way in which this material is different is that participants were familiar with the topic. The deficit problem was one of the most important political problems at the time the study was run. Although the level of political expertise varied among participants, all had at least some understanding of the problem prior to the study and had heard about it in the media. It is well known that the content of a problem can affect performance (Ericsson, 1994). Furthermore, the ability to use structure in problem solving has been shown to relate to expertise in a specific domain (Ericsson, 1994). It is possible that the ability to use structure displayed by participants in the first two studies was not due to the methodology used, a production paradigm, but rather to the content of the problem, a real-world relevant and known political problem.

Study 3

To test this possible alternate explanation, we ran a third study using the same analogies but in a reception paradigm. The goal was to keep constant the content of the analogies, while varying the task, to see whether this would influence participants' ability to use structure. This study uses the same type of methodology employed by most studies of analogical retrieval: a reception paradigm. Participants are first asked to read a set of sources. Later, they are presented with targets and asked to retrieve one of the initial sources. The sources and targets used were taken from the production of the participants in the first two studies. The interest here lies in seeing whether retrieval will be based on structural or superficial similarity. If the content of a problem determines whether people can use structure in the retrieval of analogical sources, then retrieval in this case should be based on structural similarity. If the increased ability to use structure seen in the first two studies was in fact a function of using a production paradigm, then retrieval here should be based on superficial similarity.

We selected two target arguments, one for the anti-zero deficit side, and one for the pro-zero deficit side. For each target, we selected one superficial match and one structural match. These four matches in addition to eight fillers constituted the sources that were read by participants in the first part of the experiment. Later, they were presented with the two target arguments and two target fillers. For each target, they were asked to retrieve a similar source.

Method

Participants

Twenty two undergraduate students participated in the study. They were recruited through the subject pool of the department of psychology and obtained course credit for their participation.

Materials

As mentioned previously, the stimuli for this experiment were taken from the production of the participants in the previous two studies. These analogies were separated into sources and targets (see table 5 for a list of the materials used). Of the selected targets, one was against zero-deficit (Target 1) and one was for zero-deficit (Target 2). For each target, there is one structural match and one superficial match. The structural matches are identical in structure to the target but have very low superficial similarity. They were taken from the domains of medicine (cancer) and gardening (plant), domains very different from the target domain of politics and economics. The superficial matches contain elements that

are highly similar to the ones in the targets, such as money, government, debts, interest, and so on, but they have no structural overlap. The sources had to be slightly modified from their original format (as produced by the participants in the first studies) to maximize or minimize superficial and structural similarity.

Because the two targets are from the same domain, both addressing the problem of public finances, the superficial match for one target is also a good superficial match for the other target and vice-versa. Since all participants are presented with the two targets and their corresponding matches, there are two superficial matches for each target. The data will be analyzed as such.

In addition to these target and source matches, eight fillers were designed to be presented with the sources and two with the targets (see table 6). All the filler paragraphs were taken from current events reported in the media. Only events that did not mention money, finances, government, or anything else that could be superficially or structurally similar to the targets were selected. All paragraphs were carefully equated for the number of words (between 40 and 50), the number of propositions (5 or 6), and the number of times a given element was repeated across the different sentences (2).

Procedure

Participants were told the experiment was about creative thinking and was going to take place in two parts. In the first part, they were told they would have to read short paragraphs and evaluate them for pleasantness. The four sources and eight fillers were presented in a random order on a computer screen. After participants read each paragraph, a seven point scale appeared on the screen. Their task was to enter a number corresponding to their evaluation of the pleasantness of the text. During the second part, which was in fact a distracter task, participants were asked to generate ideas to complete a cartoon strip that also appeared on the computer screen. They were given two minutes to generate as many ideas as possible for each of two cartoon strips presented successively.

They were then asked to read four more paragraphs. They were instructed that after each one, they should tell the experimenter which of the ones they read in the first part of the experiment that current text reminded them of. The four paragraphs consisted of the two targets and two fillers. The participants' answers were tape recorded.

There were two different conditions. In one condition, the participants were asked to say "Which of the paragraphs you read in the first part is this one similar to". In another condition, they were asked "Which of the paragraphs you read in the first part would make a good analogy to this one". We wanted to examine whether asking specifically for an analogical match would increase the number of retrievals based on structural similarity. Traditionally in this type of experiment, people have asked the first type of question (Gentner et al., 1993), probing for "similar" and not specifically "analogically similar" sources. We know that when no retrieval of sources from memory is involved, people interpret analogical similarity as structural correspondence (Gentner et al., 1993). It might be the case that asking specifically for analogical similarity would provide different results than simply asking for similarity.

Materials Check

Before drawing any conclusions, we needed to verify whether the structural matches selected for this experiment were actually perceived as good analogies by independent raters. We asked another group of participants (n=8) to read the targets, sources and fillers and choose, for each target, which other paragraph would make the best analogy. For each of the two targets, all participants chose the structural match as the best analogy, confirming that these matches were indeed perceived as better analogies than the superficial matches when no retrieval from memory was needed.

Results

For each target, retrievals could be one of three types: A superficial match, a structural match, or a filler. Because all sources were presented to all subjects, the structural

match for Target 1 was coded as a filler for Target 2 and vice-versa. Also, if a participant answered any of the two superficial matches for any target, it was taken as a retrieval of a superficial match since the two targets were from the same domain and were highly similar in surface to each other.

Differences between Conditions

Whether we asked for similarity or analogical similarity did not result in any difference in the proportion of superficial and structural match retrieved. A chi square performed on type of match retrieved reveals the two conditions did not differ in the proportion of structural, surface matches and fillers retrieved, $\chi^2(2, N=44) = 0.838, p > .05$. This was true for each of the two targets separately (target 1: $\chi^2(2, N=22) = 1.077, p > .05$; target 2: $\chi^2(2, N=22) = 2.207, p > .05$). We therefore combined the data from the two conditions for all subsequent analyses.

Retrieval of Structural and Superficial Matches

Participants mainly retrieved based on surface similarity. A chi square was performed to compare the number of times each type of match was retrieved to expected frequencies. This analysis indicates that retrieval was mainly based on superficial similarity (figure 3), $\chi^2(2, N=44) = 97.228, p < .001$. As can be seen in figure 3, the proportion of superficial matches retrieved far exceeds the proportion of structural matches and of fillers. For the two targets combined, 65% of retrievals were based on surface similarity and 16% based on structural similarity. Specifically, for Target 1, 16 participants retrieved a superficial match compared to one retrieval of the structural match, $\chi^2(2, N=22) = 53.73, p < .001$. For Target 2, 13 retrieved a superficial match and six retrieved the structural match, $\chi^2(2, N=22) = 52.367, p < .001$.

Retrieval based on the two target fillers did not show such a pattern. Retrieval in this case was not significantly different from expected frequencies, $\chi^2(2, N=44) = 0.492, p > .05$.

General Discussion

The main finding emerging from this study is that the use of a production paradigm allows participants to generate analogies based on deep structural features. Participants were not highly constrained by superficial similarity. These findings are surprising given the results of previous laboratory tasks but closely mirror what we have found in real-world investigations of analogical reasoning (Blanchette and Dunbar, 1997; Dunbar, 1995; 1997). Previous work on analogical reasoning has mainly, although not exclusively (Wharton et al., 1994), focused on the influence of superficial similarity in the retrieval of source analogs (Gentner et al., 1993; Keane, 1987). We have found in studies of real-world scientific and political reasoning that most of the analogies generated were based on deep structural features rather than superficial features (Blanchette & Dunbar, 1997; Dunbar, 1995; 1997). The results presented here also show that most of the sources generated by participants had little superficial similarity to the target problem. This was especially true when participants worked individually. The groups' production was somewhat more influenced by superficial similarity. Groups produced a greater proportion of analogies with high superficial similarity to the target problem and their evaluation of analogies was also influenced by superficial similarity, which was not the case for the individuals. Still, participants in both conditions were able to generate analogies exhibiting deep structural similarity between source and target. The third study showed that this ability to use structure in the generation of analogies was not due to the type of materials used. If the ability to use structure was due to participants' familiarity with the content of the problem, then we would expect that in a different methodology but with the same analogies participants would be able to retrieve based on structure. This was not the case. When using the same analogies in a reception paradigm, participants were not able to retrieve sources based on structure but retrieved overwhelmingly based on surface similarity.

Why does the generation of analogies lead to a focusing on structural features, whereas being asked to remember which source is most similar to the target lead to a focus

on superficial features? One hypothesis is that the type of encoding required for production and reception tasks is different. In the reception task, participants were asked to rate each passage (sources and fillers) for pleasantness. Previous studies that have concluded that people retrieved based on superficial similarity have used similar types of methodology and instructions. It may be the case that the standard paradigm implicitly cues the subjects to encode superficial features and hence these features are used in retrieving analogical sources. In the production task used in the current series of experiments, it is highly likely that people encoded the target problem in terms of structural features and therefore were able to retrieve analogical sources based on structural similarity. Thus, the type of encoding of both the source and the target will determine whether superficial or structural matches will be used.

Another possible explanation for the finding that subjects generated structural analogies is that they had considerable knowledge of the target and source domains before entering the experiment. However, in the third experiment we used the same target problem and picked familiar sources that subjects had generated in the first two experiments: cancer and family. Thus, it is not the amount of knowledge of the source domains but rather the type of encoding and retrieval that differed between the production and reception tasks. The results suggest that type of cognitive processing required will determine what type of similarity retrieval of sources is likely to be based on.

A further alternate explanation for the findings of these experiments could be that people retrieve but spontaneously reject all superficial matches, especially because they were asked to generate persuasive analogies. If this were the case, most of the retrieval would be based on surface similarity but the analogies the subjects reported would be based on structural similarity because those would be the only ones that survive the evaluation stage. However, there are two reasons why this is an unlikely explanation for the results. First, it is possible for analogical sources to be both structurally and superficially similar to the target. If people's retrieval was based on surface similarity but they then rejected all those that did not have structural similarity, most of the analogies would still be superficially similar, that is, both superficially and structurally similar. Second, although it is true that participants in the generation task were asked to come up with persuasive analogies, which could promote the rejection of exclusively superficial matches, the participants in the reception task were asked to retrieve "what would make a good analogy". We used these instructions knowing that people generally interpret "a good analogy" as meaning a good structural match (Gentner et al., 1993). If evaluation were responsible for the differences observed between the two tasks, people should also have rejected the exclusively superficial match in the reception task.

One final possible explanation for our results is that subjects in the generation task were not really retrieving sources but rather were retrieving analogies already stored in memory, ones they have heard in the media or elsewhere. It is possible that participants have heard such analogies given that the deficit issue was one of the most important political debates at the time we ran the study. However, it is unlikely to be responsible for the results obtained here. First, if people in the generation task really were familiar with a set of analogies on the deficit issue, this should also be true of participants in the reception task. In this case, people in the reception task would be even more likely to retrieve these already stored analogies since they had read the sources just a few minutes before they read the target. This should have facilitated retrieval of the structural match. The second reason why it is unlikely that people were retrieving already stored analogies is the diversity present in participants' production. Participants generated sources from nine different source categories and substantial amounts were not even classifiable into any category. We saw in the participants' production a diversity that we, as careful observers of the debate over the deficit, have never seen in the media. If people were really retrieving pre-stored analogies, there would have been much less variation in the types of sources used.

The different types of structure underlying the analogies produced by participants in the first two studies were very complex. A set of first-order relational statements were used

in each of the Anti and Pro-zero deficit conditions. These first-order relational structures were combined in different ways and were accompanied by additional premises or consequences to produce the different structure categories. Each of these structure categories basically corresponds to the underlying structure of an argument that can be used to argue for or against zero deficit. For example, Structure Category 1 (X is needed; If X is eliminated; Then negative consequence; Therefore don't eliminate X) corresponds to a basic Anti-zero deficit argument to the effect that social costs like insecurity, poverty and violence will result from the elimination of social support systems. In the Pro-zero deficit condition, structure category 10 (Y makes you subservient to other; Therefore eliminate Y; Therefore can be free) also corresponds to a basic argument of the Pro-zero deficit side, namely that substantial debts cause governments to be vulnerable and dependent upon the lenders.

Subjects were able to abstract out the underlying structures of political arguments and in turn use those in the generation of analogies. This is in line with other findings showing that, through reasoning, people are able to extract structure out of complex political problems and in turn use this structure for analogical reasoning (Faries and Reiser, 1990). Some of the structures used by participants in this experiment integrated parts of arguments presented in the introduction (structure categories 1, 2, 3, 6, 8, and 10). Other structure categories correspond to arguments that were not presented in the introduction (structure categories 4, 5, 7, and 9). In any case, the surprising finding is that subjects were able to use the underlying structure of these arguments to produce analogies rather than being constrained to generate analogies based on superficial similarity to the target problem as could be expected given the findings of previous experiments on the retrieval of source analogs (Gentner et al., 1993; Keane, 1987).

The use of a production paradigm allowed us to broaden our understanding of analogical reasoning. Similarly, other researchers have recently resorted to “generative” paradigms in different areas of reasoning. Ward (1994) asked subjects to imagine animals living on another planet. Bassok, Chase, and Martin (1998) asked subjects to construct arithmetic word problems. In both cases, the results showed that people relied on some type of structural knowledge, derived from semantic interpretation or general knowledge, to generate new instances. The results obtained here also exemplify how people can use underlying structure in generating new exemplars. There are, however, also some differences. The study on the generation of new animals showed that the same features people attend to when categorizing, including superficial and structural features, influence the generation of new instances. In our case, we showed that the constraints governing people’s behavior in reception tasks do not necessarily apply in the same way in production tasks. Inevitably, there will be differences between production tasks depending on the domain of reasoning investigated. However, it is important to use production or generative tasks to identify if and how the constraints identified with the use of reception paradigms apply to other reasoning situations.

Analogies produced by participants in this study resemble those studied in real-world reasoning environments in many ways (Blanchette and Dunbar 1997; Dunbar, 1995; 1997). First, they were based on deep structural features and few were taken from domains similar to the target domain. Second, elements of the source were not all explicitly related to their counterpart in the target. In fact, many analogies were mostly implicit. The sources were described but explicit connections were not drawn to the elements in the target. This was left up to the hypothetical audience. In real-world reasoning contexts too, analogies presented are not totally mapped out. Inferences about the mapping are left up to the audience. It is possible that sources are chosen so that these mappings are obvious.

Another interesting set of findings relates to the evaluation of analogies. We have shown that it is possible for superficial features and for the degree of elaboration of the source to play a role in the evaluation of analogies. In general, analogies selected as best contained a greater number of elements in the source and target. It is possible that, in fact, the analogies showing a greater degree of elaboration are perceived by the subjects as being better, more convincing or more persuasive. It is also possible that, when an analogy is

being proposed, the ones that are perceived to be good are given more attention and that the group or individual spends more efforts on the elaboration of those sources. This finding adds onto other findings relating to the evaluation of analogies (Clement & Gentner, 1991; Holyoak & Thagard, 1995). The importance of structural soundness in the evaluation of analogies, as identified by Clement and Gentner (1991), is probably a general criterion used for analogies of all types. However, it is possible that more specific criteria, related to the goal of the analogizer (Dunbar, 1995; Holyoak & Thagard, 1989) are added for the evaluation of certain types of analogies, in this case, persuasive political analogies. In fact, it is also possible that the degree of elaboration in the source is closely linked to the structural soundness of an analogy. The greater structural similarity, the greater number of elements mentioned in the source and target.

Overall, this study has provided new insights into the ways in which people use analogical reasoning. The use of a production paradigm was motivated mainly by the discrepancies seen between the findings of standard psychology experiments and real-world investigations of analogical reasoning. This supports the necessity for cross-fertilization between real-world (*invivo*) and laboratory investigations (*in vitro*) of cognitive phenomenon (Dunbar, 1993, 1995, 1997). While laboratory experiments allow for more detailed and controlled investigations of the processes to be studied, real-world data can, and do provide new knowledge and avenues to be investigated. These new insights obtained from looking at real-world examples of the cognitive processes under study can be brought back into the laboratory and scrutinized in a more controlled fashion, as was done in the present studies. The interplay between these two types of investigation is crucial to further our understanding of human cognitive abilities.

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Appendix A

Introduction to the Issue of Zero Deficit

Important problems faced by most governments and societies are national debts and budgetary deficits. Most people agree that the debts governments have contracted over the years have become a very important problem which needs to be addressed. The budgetary crisis and its related problems occupy an important place in the media.

The basic problem is that governments spend more than they earn, which produces a deficit (the difference between earnings and expenses for a given year). The income of governments mainly comes from taxes and government-owned industries, and the spendings are devoted to services to the population and support for those who need it. When spending is greater than incomes, the governments have to borrow money either from banks, citizens (savings bonds, for example), or lenders outside the country. The total amount that is borrowed is the debt. Interest runs on this debt, and the government has to pay this interest or else it increases the amount of the debt. Annual deficits accumulate and produce an enormous debt which means more interest to pay, which means more expenses, therefore more borrowing, and so on. An important problem with substantial government debts is that, like for individuals, the borrower is vulnerable and dependent upon the lender. This problem is especially acute when money is borrowed from lenders outside the country.

Our governments in Canada face this problem. The Canadian federal debt amounts to approximately 620 billion dollars with an annual deficit of 24 billion dollars. The Ontario deficit for 1996-1997 is of approximately 8.1 billion dollars. The Québec deficit for the same period is 3.2 billion dollars with a total debt of 75 billion dollars. In Québec, for each dollar paid in taxes, 16 cents go to the management of the debt.

This state of affairs has led to a wide consensus that governments have to reduce deficits. Most people consider that public finances represent a very important problem that must be addressed. The goal, ideally, is to eliminate the deficit so the debt can at least stop growing.

This is where agreement stops and disagreement begins. Although a multitude of different positions exist, two basic views oppose one another in this war on the deficit. One view is that reducing the deficit should be the number one and most urgent priority. The opposing view considers that it is important to reduce the deficit, but not at any cost.

The governments of Ontario and Alberta have adopted the first view and made the reduction of the deficit their number one and most urgent priority. To attain this goal, they have had to announce or proceed to a drastic reduction in government spending. This has amounted to massive cuts in social assistance, university funding, health services, arts and culture, and school financing, to name a few. It has also meant the loss of many jobs in the public services. In Ontario, up to 1/3 of government jobs could be cut in order to reduce the government's expenses. This policy has resulted in a balanced budget for Alberta, and possibly a budgetary surplus for the year 1996-97 that could be allocated to the payment of the debt. In Ontario, the deficit will be eliminated by the year 2001 and taxes have been and will again be lowered to reach a total reduction of 30%.

A growing number of voices are starting to speak out against what they consider to be ruthless cuts to the social programs. Specifically, substantial portions of the union movement, of community groups, and of the student movement are saying that they agree with the reduction of the deficit, but not at any cost. "The elimination of the deficit cannot result in a social deficit." They advocate that cuts to social welfare and health services in particular will translate into social chaos. The human costs will be substantial. Some people argue that insecurity, poverty and violence will result from the elimination of social support systems. For these reasons, this movement argues that it is preferable to take more time to attain deficit zero but not to sacrifice the social security net along the way. An important movement has developed in Ontario, protesting against the cuts made by Premier Harris. In Québec, community groups are asking that the government stop targeting the most vulnerable groups (e.g., welfare recipients, single-parent families, etc.) when making

budgetary cuts. Also, a strike movement by the government workers has been mentioned as a possibility in the last few days.

Appendix B
Instructions

Anti Zero Deficit Condition

You are a group of consultants and you have been hired by the National Association of Community Groups (NACG). The NACG is currently organizing an important nationwide campaign to sensitize both citizens and governments (federal and provincial).

The NACG is aware that analogies, comparing one thing to another, are a powerful tool for persuasion. Some analogies have already been used in a number of occasions in politics. For example, in 1992 President Bush wanted to convince the American population of the importance of the military intervention in the Persian Gulf. In his efforts to do so, he made extensive use of the analogy to World War II, comparing Saddam Hussein to Hitler.

The NACG has hired your group of consultants to come up with analogies that they could use to persuade the public and the government leaders that the reduction of the deficit is an important goal but that it should not be pursued at any cost. They do not agree with reducing the deficit if it means less support for those who need it and massive cuts to health, education and social assistance, less jobs, and more poverty. They want you to provide them with a list of analogies that support and illustrate this position.

You have twenty minutes to complete this task. You will be videotaped. You should brainstorm and come up with as many analogies as you regardless of how good you think they are. You write down briefly each analogy you come up with on a piece of paper, again, regardless of how good you think they are. Do not worry also about what is and what is not an analogy. Include metaphors, comparisons, everything that you think might be an analogy or something resembling. I will be in a separate room. I will come back when the time allowed for the task is up.

Pro Zero Deficit Condition:

You are a group of consultants and you have been hired by the National Association of Responsible Citizens (NARC). The NARC is currently organizing an important nationwide campaign to sensitize both citizens and governments (federal and provincial).

The NARC is aware that analogies, comparing one thing to another, are a powerful tool for persuasion. Some analogies have already been used in a number of occasions in politics. For example, in 1992 President Bush wanted to convince the American population of the importance of the military intervention in the Persian Gulf. In his efforts to do so, he made extensive use of the analogy to World War II, comparing Saddam Hussein to Hitler.

The NARC has hired your group of consultants to come up with analogies that they could use to persuade the public and the government leaders that the reduction of the deficit should be our number one priority. They think that governments do not have a choice and that citizens have to make some sacrifices. They want you to provide them with a list of analogies that support and illustrate this position.

You have twenty minutes to complete this task. You will be videotaped. You should brainstorm and come up with as many analogies as you can, regardless of how good you think they are. You should write down briefly each analogy you come up with, again, regardless of how good you think they are. Do not worry about what is and what is not an analogy. Include metaphors, comparisons, everything that you think might be an analogy or something resembling. I will be in a separate room. I will come back when the time allowed for the task is up.

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Footnotes

1. This problem involves two analogous stories. One involves a fortress that a general wants to attack. To achieve this goal, the general splits his army into small groups that converge onto the fortress. The other story is about a doctor with a patient that has a tumor. The tumor must be destroyed but rays of the sufficient intensity would destroy not only the tumor but also the healthy tissues. Participants are asked to find a solution to this second problem.
2. This term was first used by Bruner, Goodnow and Austin (1956) in the context of concept attainment to denote situations in which subjects are given instances of a concept, rather than selecting them.

Table 1
Semantic Source Categories, Study 1

Source category	Example	<u>n</u> (%)
Animals/farming	“If you have a farm, and you decide that it’s too expensive to buy pesticide, for your apples, but then all your apples die.”	5 (3.6)
Domestic tasks	“The deficit is like lint in your dryer. If you don’t pull it out, it just accumulates and blocks, and it becomes inefficient. (...) - It will grow and render the machine inoperable.”	6 (4.3)
Eating	“Cutting a little of social programs today will ensure their continuance in the future, like an apple pie, without immediate restraint on eating, the pie will disappear and there will be none left for the future eaters the next day.”	9 (6.5)
Fables/characters	“There’s the custard pot and there’s the girl and she leaves it unattended and the custard pot, it’s a magic one, it keeps making custard. So you can think debt here. It just keeps bubbling over because she’s not paying attention to it.”	7 (5.1)
Illness/medicine	“The deficit is like cancer, you have to get rid of it. - Also, it multiplies if you don’t take care of it. (...) the whole idea is that it gets worse.”	12 (8.7)
Economics/ politics	“There was a government in England in the 70’s, a labor government (...) that had a lot of social programs, and in the end, they just got too far into debt and they had to go to the IMF and say we need a loan and the IMF said well, we won’t give you the loan unless you change your programs (...) if we want to maintain our ability to make or own decisions about policies, we have to stop this now before it takes control of us.”	28 (20.3)
Source category	Example	<u>n</u> (%)
Natural resources/ disasters	“Throwing all the water on one flaming ember and forgetting the adjacent (roaring) fire.”	19 (13.8)
Personal finances	“So it’s like a baby and you want the baby to grow up well. So to do that, you don’t sacrifice all the care for the baby until it’s 18 years old just so you can have enough money then to send it to college (...) you have to care for it all along cause early damage could create more damage later on.”	18 (13.0)
Sayings/expressions	“I’m thinking of “A chain is only as strong as its weakest link” (...) the most vulnerable people have to be strengthened, not weakened.”	11 (8.0)
Others	“The government is writing a great last page to a novel without including the rest of the story.”	23 (16.7)
Total		138 (100)

Table 2
Structure Categories, Study 1

Category number	Target	Relational structure common to source and target	n
Anti-zero deficit condition			
1	SP is needed If SP is cut Then negative consequence Therefore: don't cut SP	X is needed If X is eliminated Then negative consequence Therefore don't eliminate X	11
2	If SP is cut Then solve D in the short term But If SP is cut Then more problems in the long term	If cut X Then solve Y in short term But If cut X Then more problems in long term	7
3	SP is needed If only focus on D and neglect need for SP Then negative consequence	X is needed If only focus on Y and neglect X Then negative consequence	14
4	If want to help people Then solve D If want to solve D Then have to cut SP If cut SP Then negative consequences for people	If want to help people Then solve Y If want to solve Y Then have to cut X If cut X Then negative consequences for people	6
5	Present solution: cut SP to solve D Alternate solution: Do Z instead of cut SP to solve D	Present solution: Cut X to solve Y Alternate solution: Do Z instead of X to solve Y	8
Pro-zero deficit condition			
6	D grows exponentially If solve D now Then less problems If solve D later Then more problems	Y grows exponentially If solve Y now Then less problems If solve Y later Then more problems	15
7	SP are not needed And cannot afford SP Therefore should cut SP To solve D	X is not needed And cannot afford X Therefore should cut X To solve Y	4
8	If D not solve Then negative consequences Therefore should solve D	If Y not solved Then negative consequences Therefore should solve Y	16
9	If do M (minimal effort) Then wont solve D If do L (large effort) Then will solve D	If do M Then wont solve Y If do L Then will solve Y	9
10	D makes you subservient to other Therefore eliminate D Therefore can be free	Y makes you subservient to other Therefore eliminate Y Therefore can be free	10
Others			28
Total			128

Note. SP: Social programs (a specific one or social programs in general); D: Debt problem; M: minimal effort; L: large effort.

Table 3
Source Categories, Study 2

Source category	<u>n</u> (%)
Animals/farming	5 (4.0)
Domestic tasks	3 (2.4)
Eating	7 (5.6)
Fables/characters	4(3.2)
Illness/medicine	14(11.3)
Economics/politics	8 (6.5)
Natural resources/disasters	6 (4.8)
Personal finances	17 (13.7)
Sayings/expressions	6 (4.8)
Others	54 (43.5)
Total	124 (100)

Table 4
Structure Categories, Study 2

Category number	Target	Relational structure common to source and target	n
Anti-zero deficit condition			
1	SP is needed If SP is cut Then negative consequence Therefore: don't cut SP	X is needed If X is eliminated Then negative consequence Therefore don't eliminate X	13
2	If SP is cut Then solve D in the short term But If SP is cut Then more problems in the long term	If cut X Then solve Y in short term But If cut X Then more problems in long term	8
3	SP is needed If only focus on D and neglect need for SP Then negative consequence	X is needed If only focus on Y and neglect X Then negative consequence	8
4	If want to help people Then solve D If want to solve D Then have to cut SP If cut SP Then negative consequences for people	If want to help people Then solve Y If want to solve Y Then have to cut X If cut X Then negative consequences for people	21
5	Present solution: cut SP to solve D Alternate solution: Do Z instead of cut SP to solve D	Present solution: Cut X to solve Y Alternate solution: Do Z instead of X to solve Y	2
Pro-zero deficit condition			
6	D grows exponentially If solve D now Then less problems If solve D later Then more problems	Y grows exponentially If solve Y now Then less problems If solve Y later Then more problems	17
7	SP are not needed And cannot afford SP Therefore should cut SP To solve D	X is not needed And cannot afford X Therefore should cut X To solve Y	3
8	If D not solve Then negative consequences Therefore should solve D	If Y not solved Then negative consequences Therefore should solve Y	8
9	If do M (minimal effort) Then wont solve D If do L (large effort) Then will solve D	If do M Then wont solve Y If do L Then will solve Y	14
10	D makes you subservient to other Therefore eliminate D Therefore can be free	Y makes you subservient to other Therefore eliminate Y Therefore can be free	2
Others			11
Total			107

Note. SP: Social programs (a specific one or social programs in general); D: Debt problem; M: minimal effort; L: large effort.

Table 5
List of materials, Study 3

Target		Sources	
		Superficial match	Structural match
Target 1	<p>The Canadian government has an important debt. The Canadian population also needs a good health care system. When the government only focuses on reducing the debt and does not attend to the important need for health services, the population suffers.</p>	<p>Buying medication for a child who is sick can be very expensive for parents who are not covered by an insurance plan. This is one of the reasons why the government created the Quebec drug insurance plan under which everybody is insured.</p>	<p>A plant is in much need of some water. Plants in general also need sunshine. If the owner of the plant only gives it adequate amounts of water and forgets to put it where it can get enough sunshine, it will die.</p>
Target 2	<p>The national debt grows exponentially. If the government reduces expenses now, interest on this debt will stop accumulating. If he waits until later to proceed with the cuts, interest will continue to</p>	<p>A young couple is unsure about whether they should buy a house or not. Buying a house implies having a big debt and paying lots of interest for many years to come. On the other hand, this is</p>	<p>Cancer is an illness that progresses rapidly. If a patient undergoes chemotherapy immediately, the tumors will stop growing. If this person waits to proceed with therapy later, tumors will</p>
Target		Sources	
		Superficial match	Structural match
	<p>accumulate and the debt will be harder to pay off.</p>	<p>an investment unlike rent.</p>	<p>continue to multiply and the cancer will be a lot more difficult to eradicate.</p>

Table 6
Example of filler paragraphs, Study 3

Fillers	
Source filler	<p>A women is planning a 1500 mile solo-trek across Antarctica. She has been training for this expedition for the past two years. Her training has included 10-mile runs and hours of weight training each week. During her expedition, she'll take in about 5,000 calories a day and expend about 6,000.</p>
Target filler	<p>A school teacher recently started a Girls' Club. In this club, the girls get to talk about anything they want. The goal is to empower girls to retain strong identities and avoid different problems such as depression and eating disorders.</p>

Figure Captions

Figure 1. Choice of best analogy and source category, Study 1

Figure 2. Choice of best analogies and number of elements explicit in the source and target, Study 2

Figure 3. Retrieval of superficial and structural matches for targets and fillers





