Dynamic Use of Multiple Analogies in the AMBR Model Causing Re-Representation of the Target

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Abstract

This paper describes how the AMBR model explains multiple analogies and more specifically how the use of a superficially similar analogical base, that turns out to be inappropriate (we call it a bridge analogy), may actually lead to the re-representation of the target and the activation of a more appropriate remote analogical source. A simulation is described that demonstrates this capability of the model. A specific prediction of the model about the re-representation that the presence of the bridge analogical source is causing is tested in a psychological experiment.

Introduction

Analogy-making is considered a basic cognitive process that underlies much of human cognition (Hofstadter, 2001; Holyoak, Gentner, Kokinov, 2001). That is why a lot of effort has been put to investigate this fundamental cognitive ability (Holyoak, Gentner, Kokinov, 1998; Gentner, Holyoak, Kokinov, 2001; Kokinov, Holyoak, Gentner, 2009).

Most of this research, however, is devoted to understanding single analogies, i.e. analogies between a target and a single source. While this is certainly a very wide spread phenomena, multiple analogies (i.e. analogies between a target and multiple sources) do play an important role as well. There are two reasons for the use of multiple analogies. The first reason is that it is rarely the case that there is a single past experience which matches the current situation well enough to solve the problem at hand. We can, however, combine several previous cases each of which partially maps to the target to collectively help solving the problem. In the early days of analogy research there were some interesting studies of multiple analogies in physics (Collins &Gentner, 1987, Clement, 1993), in astronomy (Gentner&Markman, 1997, Gentner, at al., 1997), in medicine (Spiro et al., 1989), in biology, archeology and philosophy (Shelly, 1998, 1999, 2003), in computer science (Burstein, 1986, 1988). There were even some initial computational models of multiple analogies that were trying to explain how the information from different sources is being integrated – CARL. (Burstein, 1986, 1988) and a special version of the Multiple Constraint Theory (Holyoak &Thagard, 1989) suggested by Shelly (1999). However, later on the mainstream research in the field of analogy has concentrated on the single analogy case (Gentner, 1983, 1989, Falkenheiner at al., 1989, Holyoak &Thagard, 1989, Hummel & Holyoak, 1997, Kokinov &Petrov, 2001).

This paper is an attempt to shift the focus again to the study of multiple analogies, but from a new perspective. There is a second reason to use multiple analogies: the first analogy that comes to our mind may not necessarily be the best one and we may benefit from rejecting it and searching for another solution. The first analogy could however play the role of facilitator that invites better matches to the target. Some call it “a bridging analogy". We are interested in the dynamics of the re-representation processes that such bridging analogies trigger and how they facilitate the multiple analogies production.

The concept of “bridging analogies” was first introduced by John Clement and then used by Stella Vosniadou and others (Clement, 1993, 2009, Vamvakoussi &Vosniadou, in press, Vosniadou & Skopeliti, in press). The idea is that the teacher can provide an intermediate analogical base that will be in-between the target and the desired remote analogical source. They have experimentally shown that children, students and even experts make the desired remote analogy easier if there is such a bridging analogy provided by the teacher of physics or mathematics.

In contrast, we are interested in the mechanisms of spontaneously self-generating of such bridging analogies and what their effect could be on the re-representation of the target and subsequent search for better analogies. The next section describes a simulation experiment which demonstrates the capability of the AMBR model to spontaneously come up with bridging analogies and use them in further search of a better remote analogy. Then we present the results of a psychological experiment which tests what the influences of this bridging analogy are on the evaluation of the desired remote analogy.

Simulation

The AMBR Model

We have used the AMBR model for simulating the process of spontaneous multiple analogy-making, including the generation of bridging and remote analogical sources. The general AMBR model is described elsewhere (Kokinov, 1994, Kokinov &Petrov, 2000, 2001) and to save space it will not be presented here again. Crucial features of AMBR are the decentralised representation of episodes which allows for context-sensitive construction of the episode.
descriptions (past episodes are not stable static structures but are dynamically constructed on the fly); the continuous change of the relevance of the various representational elements which allows for dynamic processes of representation building and re-representation; the emergent computation processes which are based on local information processing only and depend on the computed relevance of the memory elements which allows for exhibiting context-sensitive computation.

In previous work we have demonstrated how perception and analogy-making interact in AMBR thus allowing for dynamic re-representation of ambiguous input stimuli under the pressure of the analogy-making process (Kokinov, Bliznashki, Kosev, Hristova, 2007; Kokinov, Vankov, Bliznashki, 2009). In the following simulation we are exploring AMBR’s capability to produce several analogies one after another and exhibit dynamic re-representation of the target as result of these intermediate analogies.

Overview of the Simulation

The goal of the system is to find an appropriate remote analogy for the case of “a suicidal terrorist act, made by a single terrorist”; and if possible, to transfer additional knowledge or even a proposal for how to prevent further similar acts. One superficially similar potential base is the suicidal act of a kamikaze during the World War II. We expect the system easily to activate this base and to launch the analogy. However, this analogy is not good and will fail later on. The reason is that one vivid aspect of the kamikaze profile is their motivation: the kamikaze is typically coming from a wealth family; they are proud of their origin and culture, of their country; they perform their suicide act with pride and for the prosperity and safety of their country.

Once activated, the motivational aspect of the kamikaze situations will try to map with its analog in the terrorist situation. Thus, the question about the deep psychological motivation of the terrorist’s act will be activated.

However, the encoded knowledge about the terrorist’s motivation is that he has been an immigrant for several years already; and although he has good educational and relatively good professional achievements, he is not happy. He has never overcome the cultural differences, the guilt he experienced for leaving his country; and his nostalgia.

Once activated, this aspect of the target situation could activate a completely different base. Namely, the base of a Bulgarian immigrant in Ireland who has the same problems to adapt himself to a different culture and, as a consequence, he regularly beats his wife. Despite the fact that this base is quite different from the terrorist’s one, we expect it to win the analogy because of the deep structural analogy taking into account the motivation.

The last step for the system is to make a transfer. The story about the Bulgarian emigrant in Ireland has a happy continuation. This man has found a solution and has solved his problems. Actually, he has opened a Bulgarian restaurant and a small shop for traditional Bulgarian souvenirs. Thus he has never uprooted fully from his country and, on the other hand, has deserved a respect from the Ireland people. Solving his self-esteem problem made him stop beating his wife.

Dynamics of the simulation

The target situation is represented with eight instance AMBR-agents (fig. 1). Two of them stand for the terrorist himself and for the suicidal act.

![Figure 1](image)

These two nodes are directly attached to the INPUT and the activation spreads to the respective concepts and then back to some other known instances.

The other agents (in white on the picture) from the terrorist situation represent different aspects that the system ‘knows’ in principle about the terrorists but these aspects are not activated at this moment. For example, a coalition of agents represents the deep motivation for the suicidal act of the terrorist – he is unsatisfied because of nostalgia or unacceptability of the cultural differences. However, there are not any links from the active elements to this aspect and as a consequence, the system does not ‘think’ about this at the beginning.

The agent ‘more acceptable act’ is attached to the GOAL node. Its purpose is an eventual solution to be transferred from somewhere to this agent. This agent is not connected to any other agent except its respective concept-agent.

Some other marginal pieces of knowledge are represented – for example the fact that the traditional culture is very rich and potentially interesting for foreigners.

One binding-node (not shown on fig.1), represents the whole situation. All other agents point to it, but there are few opposite links and all aspects of the situation cannot be activated from a single element.

During the first 5 AMBR cycles the activation spreads through the concepts of “suicide” and “terrorist” and then back to some typical instances. As the concept of a “kamikaze” is assumed to be a typical instance for a suicide, there is a top-down link from the concept of “suicide” to “kamikaze”. The ‘kamikaze’ situation is represented again by a ‘kamikaze’ and ‘suicide’ nodes and, as in the target situation, the action ‘suicide’ is a relation with one argument – ‘kamikaze’. This allows these pairs of nodes to be easily mapped (see Figure 2).
Figure 2. The mapping between the “terrorist” and “kamikaze” situations occurs at the 10th AMBR cycle. The hypothesis agents are represented with diamonds.

Once activated, the node for ‘kamikaze’ spreads activation to some other agents. The deep motivation for the kamikaze’s suicide is his honor of his nation, emperor and family. Thus, the activation spreads to the abstract concept of motivation in general, then back to the more concrete concepts and instances, including the motivational aspect of the terrorist’s act which starts slowly to become active (Figure 3).

Figure 3. Between the 6th and the 19th AMBR cycles the motivational aspect of the “terrorist” story becomes active.

On the other hand, from the ‘kamikaze’ base some other concepts become also active because of a large number of associative links – ‘Japan’, ‘Shogun movie’, ‘England’, ‘Ireland’, etc. (Figure 4).

As a result of the activation of the “immigrant” base, its elements start to map to the elements of the target situation. Thus, the “kamikaze” and the “immigrant” bases become competitors for the mapping with target situation.

The ‘immigrant’ base is structurally closer to the target situation, because both share the high-order relations of the motivational cause of the respective actions. Thus, even though the actions themselves are very different (the immigrant beats his wife, whereas the terrorist makes a suicidal act), they map to each other because of the pressure for the structural mapping.

Figure 4. Between the 6th and the 17th AMBR cycles the activation spreads from the “kamikaze” base to the “immigrant” one.

Thus, at time 21 AMBR cycles (Figures 5, 6), the first mappings between the ‘terrorist’ and ‘immigrant’ situations are launched. At the beginning the ‘kamikaze’ situation is still more active and remains leading for a long period of time. The continuous structural pressure from the ‘immigrant’ situation causes an inversion of the activation of the two bases (time 34); and later on the ratings are inverted too (time 77).

Finally, at time 128 the rating for the ‘immigrant’ base exceeds the threshold 1.000 and wins the competition. In other words, the hypothesis that the binding-node of the ‘terrorist’ situation corresponds to the binding-node of the ‘immigrant’ situation becomes a winner.

Figure 5. Activation level of the binding nodes for the two base situations (‘kamikaze’ and ‘immigrant’ as a function of time). At time 128 the mapping with the ‘Immigrant’ situation wins.
The independent variable was the presence or absence of a bridge analogical base. The dependent variables were participants’ judgments of how similar the stories and some of their aspects are on a 7-point scale.

Procedure:
Each participant received a sheet of paper with three short stories printed on them. The instruction was to read carefully all three stories and to prepare for answering some questions about them. There were no time limits for reading. Everybody worked alone, with the presence of the experimenter in the room only.

The participants from the control group received the stories “Terrorist”, “Tsunami”, and “Emigrant” (in this order); whereas the participants from the experimental group received “Terrorist”, “Kamikaze”, and “Emigrant” (see more about the stories in the section Stimuli below).

After that, the participants from both groups received another sheet of paper with eight statements on each. The instruction was to evaluate on a 7-point scale how much they agree with each of the statements. The last four statements were equal for both groups and concern the similarity between the “Terrorist” and “Emigrant” stories, as well the similarity between some of their aspects. The first four statements differed for both groups and concerned the similarity between the “Terrorist” and “Tsunami” or “Terrorist” and “Kamikaze” stories, respectively. The object of analysis was the answers to these four, identical for both groups, questions.

Stimuli:
The four stories “Terrorist”, “Kamikaze”, “Tsunami”, and “Emigrant” consisted of 120-170 words each. The first three stories were described as journalistic coverage, the fourth one – as a letter to a friend. The “Terrorist” coverage was about a lonely man who had crashed with a car-bomb in a market in New Jersey. The “kamikaze” report was about the grandson of a kamikaze, hero from the war. The grandson has been just nominated as an ambassador of Japan to US. The story of the tsunami (a control story for the participants in the control group) was about a Japanese farmer who had lost his business because of a tsunami. The “Immigrant” story was a letter from the wife of the immigrant to her friend.

The questionnaire consisted of eight statements. The first four statements differed between the two groups. For the control group they served for evaluating the similarity between the “Terrorist” and “Tsunami” stories; for the experimental group – between the “Terrorist” and “Kamikaze” stories, respectively. People had to evaluate how similar they feel the stories as a whole; and the actions of the main protagonists; the motives for their actions, and the nature of the persons as a whole.
The second group of four questions served for evaluating the similarity between the "Terrorist” and “Immigrant” stories according to the same criteria. These four questions were the same for both groups and were the object of analysis.

**Participants:**
42 students from New Bulgarian University participated in the experiment for course credits. They were randomly assigned to both groups. 24 of them – in the control group; the other 18 – in the experimental group.

**Results:**
The mean rating of how similar the stories about the terrorist and the kamikaze was 2.25 (s = 1.23) for the control group, and 3.83 (s = 1.79) for the experimental group. The difference was statistically significant: t(40) = -3.40, p < .01.

The differences between the three aspects of the stories, (whether the actions of the characters are similar; whether the motives for the actions of the characters are similar; whether the characters are similar in their nature) were not significant: t(40) = -1.18, p = .24; t(40) = -.80, p = .43; t(40) = -1.03, p = .31, respectively.

Thus, the difference of the ratings for the overall similarity cannot be explained by a simple assimilation effect. Looking at each aspect of the stories separately, the participants in both groups do not differ in their ratings. However, it seems that people in both groups weight the different aspects of the stories differently in the context of the third story. In other words, people weight the various aspects of the mapped stories differently depending on the context. This means that they have different representations of the target situation as predicted by the simulation.

**Conclusions**

Analogy-making is a powerful instrument for decision-making and evaluation. However, retrieval of the most appropriate base for the analogy is a very difficult task both for humans and for most of the models of analogy-making. It is relatively easy to retrieve situations that share the same superficial properties with the target, but it is very hard to retrieve a situation that shares the same high-level relations. In addition, the problem becomes even more difficult if the most relevant, with respect to mapping to the right base, aspects of the target story are not considered relevant in the initial representation of the target.

We proposed an idea how both problems may be addressed by exploring the dynamics of multiple analogies. Instead of trying to retrieve the appropriate base directly, one may use one or more bridging superficial analogies that gradually direct the system to the right solution. On one hand, the bridging analogies may help for the retrieval of a better structurally but less superficially similar episode. On the other hand, the bridging analogies may cause a re-representation of the target and may highlight different aspects of it.

We used the AMBR model for analogy making to simulate this idea. One aspect of the representation of the target situation was left inactivated. The system easily extracted from its memory one superficially similar base and launched the mapping process. It was impossible for it at the beginning to activate a more appropriate base for the analogy because of its remoteness.

However, we propose at least two ways of how this remote base may be activated indirectly:

First, the initial mapping with the superficial base may cause a re-representation of the target, highlighting the non-vivid aspects of it.

Second, the superficial base may facilitate the further spread of the activation to close and far associations.

The mechanisms for structural correspondence of the AMBR model allow it to support and maintain the structurally well-organized mappings. Thus, even though the activation may spread to various bases and many different initial mappings may be launched, AMBR behaves stable enough: once the most structurally similar base is partially activated, the consistent mappings cause additional activation and it wins the competition.

The hypothesis that a third, structurally dissimilar base, may facilitate the analogy between two situations was tested in a psychological experiment. People judged with higher ratings the similarity between two situations in the context of a bridging analogy, in comparison with the same judgments in the context of an arbitrary third story. The context was designed to initiate some mappings between the target and the contextual stories. These initial mappings should make the important aspects of the target story on which the two stories differ more vivid. As a consequence, people weight these aspects higher.

At the same time, if people focus on the similarity of a certain aspect of the stories, there is no reason the context to influence their ratings. This was confirmed by the experimental results – participants’ ratings differ depending on the context only when the similarity of the whole stories should be evaluated; but not when the respective similarity between concrete aspects of the stories had to be rated.

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**References**


