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Accessing source information in analogical problem-solving

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Several studies showed that people presented with source information fail to apply it to an analogous target problem unless they are instructed to use the source. Seven experiments were carried out to assess whether such a lack of spontaneous transfer occurs because individuals do not activate the source during the target task or because they do not realize the source–target relationship. Experiment 1 compared a condition in which the source was activated with no cue about the source–target connection to conditions in which subjects were informed about this connection. Results suggested that the lack of spontaneous transfer does not depend on failure in activating source information. Experiments 2, 3, and 4 were devised to falsify this finding by activating the source closer and closer to the target and by focusing participants' attention toward the relevant aspects of the source. Experiments 5, 6, and 7 were aimed at stressing source–target correspondences by introducing surface similarities. All experiments showed that the mere activation of the source does not facilitate analogical transfer. Results suggested that two processes should be distinguished in the access phase of analogical problem-solving: Source retrieval and identification of the source–target connection.

When we have a new problem to solve (*target*), we may look for a similar situation (*source*) solved successfully in the past. In such a way the source enables us to adapt a familiar solution procedure to the target problem. This process is called *analogical problem-solving* (Gick & Holyoak, 1980).

Analogical problem-solving has recently been investigated by presenting individuals with a novel problem preceded by a story suggesting the solution strategy relevant to that problem. For instance, in several studies (Antonietti, 1991; Antonietti & Gioletta, 1995; Beveridge & Parkins, 1987; Catrambone & Holyoak, 1989; Gick, 1985, 1990; Gick & Holyoak, 1980, 1983; Holyoak & Koh, 1987; Keane, 1985, 1987; Jausovec, 1989; Spencer & Weisberg, 1986) the target task was Duncker's (1935) radiation problem, which describes a patient with a tumour within his body. High-intensity X-rays can destroy the tumour, but they also destroy the surrounding healthy tissue; low-intensity rays are harmless to the healthy tissue, but they fail to destroy the tumour. One of the possible

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solutions- the so-called "dispersion–concentration solution"- consists in sending several weak rays from different directions toward the tumour. In order to suggest this solution by analogy, the target was preceded by an isomorphic story: For example, a general who wants to capture a fortress is able to do so by sending part of his army down each of many roads converging on the fortress (Gick & Holyoak, 1980).

There is abundant evidence that people fail to transfer spontaneously the solution procedure described in the source to the target if they are not instructed about the source–target relationship. In fact, in several studies participants who were presented the source without having been informed (in between-subject designs) or before having been informed (in within-subject designs) about its relevance to the solution of the target (no-hint conditions) transferred the solution principle embedded in the source to the target in a very low percentage, not significantly different from that recorded in control conditions where no source was given. Conversely, high percentages of analogical solutions emerged when participants were told that the source might be useful to solve the target (hint conditions). Such a difference between the no-hint and the hint conditions occurred with various kinds of problems: ill-defined (Beveridge & Parkins, 1987; Catrambone & Holyoak, 1989; Gick & Holyoak, 1980, 1983; Holyoak & Koh, 1987; Keane, 1985, 1987) and well-defined (Bassok, 1990; Gick & McGarry, 1992; Hayes & Simon, 1977; Novick & Holyoak, 1991; Reed, Dempster, & Ettinger, 1985; Reed, Ernst, & Banerji, 1974); insight (Beveridge & Parkins, 1987; Catrambone & Holyoak, 1989; Gick & Holyoak, 1980, 1983; Gick & McGarry, 1992; Holyoak & Koh, 1987; Keane, 1985, 1987) and step-by-step (Bassok, 1990; Hayes & Simon, 1977; Novick & Holyoak, 1991; Reed et al., 1985; Reed et al., 1974) and mathematical and geometrical (Bassok, 1990; Novick & Holyoak, 1991; Reed et al., 1985) and practical (Beveridge & Parkins, 1987; Catrambone & Holyoak, 1989; Gick & Holyoak, 1980, 1983; Holyoak & Koh, 1987; Keane, 1985, 1987). Such a difference was found in adults (see the papers mentioned previously) as well as in children (Beveridge & Parkins, 1987; Brown & Kane, 1988; Brown, Kane, & Long, 1989; Chen & Daehler, 1992; Crisafi & Brown, 1986; Holyoak, Junn, & Billman, 1984).

Without a hint, even short time intervals between the presentation of the source and the presentation of the target failed to enhance analogical transfer (Catrambone & Holyoak, 1989; Spencer & Weisberg, 1986). Furthermore, a difference between no-hint and hint conditions was reported with experimental manipulations aimed at stressing the correspondences between the source and the target, such as varying the wording of the target so as to cue the solution schema of the source better (Catrambone & Holyoak, 1989), presenting the source story together with diagrams (Gick, 1985, 1989, 1990; Gick & Holyoak, 1983) or with an abstract principle (Gick & Holyoak, 1983), or producing a problem-oriented setting (Needham & Begg, 1991). Some studies showed that, under specific conditions, participants succeeded in transposing the solution principle described in the source to the target even though they were not given an explicit hint to do so. This, however, occurred when the source was- as authors admitted (Gick & Holyoak, 1983, Experiment 1, p. 15)- very similar to the target. For instance, Keane (1987, Experiment 1, literal analogue condition) reported that 88% of subjects retrieved the dispersion–concentration solution by presenting the source and the target, which both dealt with the radiation problem and differed from each other only in the localization of the cancer

(stomach or brain, respectively).[1] Rates of non-hinted analogical transfer (40%–52%)- which were, however, about half of those recorded in hint conditions (80%–100%: see Gick & Holyoak, 1980, 1983)- were found by giving participants two source stories and by asking them to summarize the stories and to write descriptions of how they were similar (Gick & Holyoak, 1983, Experiments 4–6), even though both Catrambone and Holyoak (1989) and Spencer and Weisberg (1986) reported a lack of spontaneous transfer after having instructed subjects to compare two sources in order to derive their common structure. In any case, we can notice that the matching of the two stories- explicitly required in some experimental conditions- led subjects to infer an abstract solution schema, which facilitated analogical transfer because, as Gick and Holyoak (1983, p. 24) remarked, "reasoning from a schema is more effective than reasoning from an analogy." So, experiments in which two sources were provided do not support the occurrence of genuine spontaneous transfer. Finally, analogical problem-solving without a hint was reported when subjects were induced to form a mental set to look for source–target correspondences (Brown & Kane, 1988), but this case also can not be considered an example of natural transfer.

In sum, if we exclude the few cases in which experimental manipulations have produced conditions that are particularly favourable in highlighting source–target correspondences, studies suggest that providing source information only is not sufficient to induce subjects to make use of it to solve a new problem analogically.[2]

This conclusion is consistent with the results of studies in which, before the presentation of the target problem, participants were exposed to information relevant to the solution of the target. For instance, Weisberg, DiCamillo, and Phillips (1978) instructed

[1] Lower percentages of analogical solutions (53–58%) were retrieved by using the story about the general as a source and by introducing in it an element that was identical (the ray) or semantically similar (the laser beam) to the corresponding element of the target problem (Keane, 1987, Experiment 2). However, in these experiments participants were told before the target task that analogy plays a role in creativity and problem-solving, and they were given examples of this role; furthermore, subjects were asked to try to think of analogous problems before attempting to solve the target problem. These instructions induced subjects- as Keane (1987, p. 34) noted- to adapt a conscious search strategy. Thus these outcomes cannot be considered valid cases of spontaneous transfer.

[2] Lovett and Anderson (1994, Experiment 3) found no significant difference between hint and no-hint groups in an experiment aimed at assessing transfer of a solution procedure from one or two previously solved geometry problems to a third target problem. However, it is worth noticing that in such a study: (1) The dependent measure was solution time and not, as in the other papers, solution rate; (2) the hint was vague (subjects were told to think back to the previous problems to solve the target). This can account for the discrepancy between Lovett and Anderson's data and findings mentioned here. The first remark can also explain why Luger and Bauer (1978)- but not Hayes and Simon (1977) and Reed, Ernst, and Banerji (1974), who employed similar materials- reported transfer between isomorphic problems without hint. Finally, Schunn and Dunbar (1996) also reported evidence of spontaneous (implicit, in their terms) analogical transfer- more precisely, of a transfer between two different domains in the absence of the awareness that a principle presented in the first domain helped the solution of a problem in the second domain. However, as the authors themselves remarked, in their study participants already had the concept to be transferred before entering the experiment, whereas in traditional investigations about analogical problem-solving participants acquire the new concept to be transferred during the course of the experiment. Furthermore, in Schunn and Dunbar's study the concept to be transferred was a general concept (inhibition) and not a novel concept uniquely tied to a particular instantiation (as, for example, the dispersion–concentration principle), which requires that details have been discarded to become suitable for analogical transfer.

participants to learn a list of word pairs. All pairs consisted of highly associated words except the critical pair candle–box. Such a pair should have suggested the solution to the candle problem (Duncker, 1935), which was given to the participants later. This problem asks people to attach a candle to the wall so that it will burn properly; they can use a box of nails, a box of matches, a hammer, and the candle. The goal can be reached by emptying the box of nails, attaching it to the wall, and putting the candle on top of or in the box. Data showed that individuals who were not told that the word pairs previously learned might be useful in solving the target did not perform better in the candle problem than control individuals who learned a list that contained the irrelevant word pair candle–paper rather than candle–box. In contrast, people who were explicitly informed about the relationship between the word pairs and the target utilized such a cue to face the candle problem successfully.

Perfetto, Bransford, and Franks (1983) reported similar findings. They first asked participants to rate the truthfulness of some sentences and then gave them a series of riddles to solve. The sentences rated earlier suggested the solution of the subsequent riddles. For example, the riddle "A man who lived in a small town in the U.S. married twenty different women of the same town. All are still living and he has never divorced one of them. Yet, he has broken no law. Can you explain?" was cued by the sentence "A minister marries several people each week". Like Weisberg et al. (1978), Perfetto et al. (1983) found that information previously given was effective in suggesting the solution to the target only when individuals were informed about the connection between the sentences presented earlier and the riddles.[3] Finally, we can notice that various studies indicated that implicit aids given to the participants before or during the target phase, without instructions to notice and use them, do not improve the problem-solving performance (Landrum, 1990).

In short, data acquired through different materials and procedures converge in demonstrating that people who are first presented with potentially relevant information fail to utilize it successively in problems in which such information may suggest a solution, unless they are told that it can help them in the target task.

The experiments reported here were aimed at investigating reasons for the lack of spontaneous transfer in analogical problem-solving. More precisely, they had three kinds of goal: (1) assessing the effects yielded by the simple reminding of the source as distinct from those yielded by the awareness of the source–target connection; (2) providing a more accurate description of the process of analogical problem-solving, which includes different phases for the source activation and for the source–target relating operations; (3)

[3] Bowden (1985) found that there was spontaneous transfer in uninformed participants when he allowed them adequate time for the solution of each riddle, and Stein, Way, Benningfield, and Hedgecough (1986) found it when they enhanced the superficial similarity between the acquisition context of the sentences and the target. In these cases, however, the relationships between the sentences and the riddles became too blatant so that the lack of transfer was unlikely to occur (Needham & Begg, 1991). For a criticism of Bowden's claim about the occurrence of spontaneous transfer see Ross, Ryan, and Tenpenny (1989): One argument of these authors is that the improvement in performance (in comparison with that of a control group that was not previously exposed to sentences describing the solution of the subsequent riddles) that emerged in the uninformed participants was due to the fact that some of these became aware of the sentence–riddle relationships during trials and so were in the same condition as the informed participants.

testing the psychological reality of theoretical models that assume that analogical transfer occurs as a consequence of an activation process.

As far as the first issue is concerned, in all studies mentioned previously, the effects of the hint- namely, of instructing participants about the relation between the source information previously given and the target problem- were twofold. First, such a hint reminded the solver of the source; second, it stressed the relevance of the source to the target. In fact, by telling people that the story told before the target problem might suggest a solution by analogy invited them both to activate in their mind the memory of such a story and to link it to the target in order to identify isomorphic elements useful to transpose the solution strategy described in the story to the different domain of the target. Thus, we cannot know whether people did not spontaneously use the source information to solve the target because in their mind the representation of such information was not activated, or because, even though such a representation was activated, they were not aware of the connection between this information and the target. In the experiments reported here we devised a procedure that allowed the separation of the two effects- that is, source activation and awareness of the source–target relationship.

With reference to the second goal, it has been maintained that analogical problem-solving cannot be reduced to a single process; rather, different operations are involved. More precisely, there is a consensus that analogical problem-solving can be divided into the following phases (e.g., Gick & Holyoak, 1983; Holyoak & Koh, 1987; Keane, 1987; Needham & Begg, 1991; Pierce, Crain, Gholson, Smither, & Rabinowitz, 1996; Reeves & Weisberg, 1994; Ross, 1987, 1989):

1. the *encoding* of the source.
2. the *retrieval* (Holyoak & Koh, 1987; Keane, 1985, 1987; Novick & Holyoak, 1991), *search* (Hesse, 1991), *selection* (Clement & Gentner, 1991; Gentner & Toupin, 1986; Holyoak & Koh, 1987; Holyoak & Thagard, 1989), or *access* (Ross, 1987; Ross & Kennedy, 1990; Schunn & Dunbar, 1996) phase, which induces individuals to recall a source relevant to the solution of the target.
3. the *mapping* (Clement & Gentner, 1991; Gentner & Toupin, 1986; Holyoak & Koh, 1987; Holyoak & Thagard, 1989; Novick & Holyoak, 1991), *use* (Schunn & Dunbar, 1996), *applying* (Gick & Holyoak, 1983; Gick & McGarry, 1992; Ross, 1987, 1989), and *adapting* (Keane, 1996; Novick & Holyoak, 1991) phases, in which subjects construct orderly correspondences between the elements of the source and those of the target to draw a solution.

Some authors (Gentner, 1989; Holyoak & Thagard, 1989; Ross & Kennedy, 1990) hypothesized a final phase in which *schema induction* occurs- that is, a phase in which subjects abstract from the source and the target a solution principle that can be applied to a wide range of structurally similar situations.

The most controversial phase is the second one. Gick and McGarry (1992) maintained that it consists of both noticing and retrieving the source; Ross (1987) first claimed that access involves reminding and retrieval and then (Ross, 1989) noticing (or selection) and retrieval; Reeves and Weisberg (1994) divided retrieval into noticing and selection. In

general, authors disagree about the distinctions to be made within this phase. Our experiments were aimed at clarifying this issue.

With respect to the third goal of our investigation, we can stress some theoretical implications concerning the role of activation in analogical problem-solving. Holyoak and Koh (1987) argued that retrieval of analogies is based on the summation of activation resulting from multiple shared features. If the sum of activation exceeds some threshold, the representation is retrieved and it can be used for further processing, such as an explicit source–target mapping. According to these authors, retrieval by summation of activation can provide a general mechanism for flexible access to information in the memory that is related to a novel input. An activation model responsible for analogical problem-solving has been proposed also by Anderson (see Anderson, 1993; Singley & Anderson, 1989). In this perspective analogical transfer occurs when the strength of the activation of the trace of the source is sufficiently high. In this case the solution procedure embedded in the source becomes so strong that it can be applied to the target so that search of new original solutions is not needed. A question raised by these models is the following: Do people, when solving a problem by analogy, really think as the models conjecture? In other words: Does an adequate degree of activation of source information really enable analogical transfer? Results of our experiments could contribute to assessing the degree of psychological reality of the mechanisms that are supposed to underlie problem-solving by analogy.

EXPERIMENT 1

In order to distinguish the mere activation of the source information relevant to the solution of the target from the relating of such information to the target, *reminding* and *hint* conditions were designed. In the reminding condition the representation of the source was activated immediately before the presentation of the target by inducing participants to retrieve the critical part of the source relevant to the solution of the subsequent task, with no cue about the connection of such information to the target. By contrast, in the hint condition (as well as in the hint conditions studied in previous papers), participants, before the presentation of the target, were told that the critical part of the source presented earlier would be useful to the solution of the target itself. The *reminding+hint* condition was devised to assess whether reminding can enhance the effects produced by the hint. Finally, a *control* condition, with neither reminding nor hint, was included; this condition corresponded to the no-hint conditions investigated in previous studies.

Method

Participants

Eighty university students, attending different humanities courses, were randomly assigned to the following groups: control, reminding, hint, and reminding+hint. In this experiment and in all the others reported in this paper, each group was composed of 20 people who were tested individually; participants volunteered and were neither paid nor did they receive course credits.

Material

Target problem. The target problem used in this experiment involves the same solution plan- that is, the dispersion–concentration schema- as Duncker's radiation problem, which is usually employed in studying analogical problem-solving and was described earlier.[4] A source story devised by Holyoak and Koh (1987) was manipulated to serve as a target problem (see Appendix A). Such a problem describes the situation in a university laboratory: A very expensive light bulb used in some experiments does not work because the filament inside has broken. The only way to repair it is to use a laser beam. A high-intensity laser beam could repair it but would also break the fragile glass surrounding the filament; at a lower intensity the beam would not break the glass but would not repair the filament.

Individuals were asked to find some procedures to repair the filament with a laser beam without damaging the glass. One of the possible solutions consists in sending several weak laser beams from different directions toward the filament: In this way the weak beams do not damage the glass and, by simultaneously converging on the filament, produce a high-intensity effect that repairs the filament.

Source. In order to suggest the dispersion–concentration solution to the target problem, the artificial-lake story (see Appendix B) was used. The situation described in the story was as follows. The construction of an artificial lake fed by a unique wide stream of water was planned. This plan showed some mishaps. So, another plan was designed which involved the construction of four small streams of water coming from different belts surrounding the lake.

The artificial-lake situation shows close structural relations to the target problem. In fact, the solution of the light-bulb problem needs to overcome two obstacles: (1) If a unique high-intensity laser beam is sent toward the filament, the beam breaks the glass; (2) if a unique low-intensity beam is sent toward the filament, it does not repair the filament. Correspondingly, in the source story there are two obstacles: (1) During flood periods, a unique wide stream of water may damage the surrounding areas; (2) during drought periods, a unique small stream is insufficient to feed the lake. Furthermore, in the target problem, according to the dispersion–concentration solution, Obstacle 1 is overcome by substituting the unique strong beam with several weak beams, and Obstacle 2 is overcome by sending several weak beams toward the filament from different directions. Similarly, in the artificial-lake situation Obstacle 1 is overcome by replacing the unique wide stream of water with several small streams, and Obstacle 2 is overcome placing the small streams in different directions, so that they convey water coming from different belts into the lake.

Procedure

The experimenter presented a booklet in which every page corresponded to a task to be carried out. Participants had to follow the instructions reported on the top of each page. In this experiment, as in the following experiments, participants were not allowed to turn back the pages of the booklet.

On the first page of the booklet there was the spy story, namely, a filler story with no relation to the target. This story concerned an important microfilm, which was successfully stolen by hiding it inside a camera. Participants had 1 min to read the story, and then they had to go to the next page. On the second page participants had 2 min to solve the following puzzle: "How many children should a married couple have to be sure to have at least two children of the same sex?" Students had to answer aloud. Even if the answer was wrong, they could turn the page. On the third page there was a

[4] Unlike previous studies, in these experiments we did not employ Duncker's (1935) radiation problem as target because in pilot studies some subjects appeared to be emotionally disturbed by the dramatic situation that it describes.

question about the spy story: Participants were asked to recall how the spy, according to the previous story, succeeded in hiding the microfilm. Participants had 1 min to answer aloud. On the fourth page participants had to examine visually two pictures in order to spot differences. After 5 min the task was over even if not all the differences had been found. The fifth page reported the source (i.e., the artificial-lake story) to be read in 1 min. On the sixth page there was a seven-letter anagram, which students had to solve in 3 min. Participants passed to the following page even if they had not solved the anagram.

The subsequent task depended on the particular condition to which participants had been assigned. In the control condition, students read the target on the seventh page and had to verbalize all the solutions that they found. This was the last task for these undergraduates; the time allowed for the task was 5 min. In the reminding condition, on the seventh page, participants found the following question concerning the source: "What did the mason suggest in the artificial-lake story?" Undergraduates had to answer aloud; after 1 min they went to the eighth page where there was the target. In the hint condition, on the seventh page, participants found this sentence: "The mason's proposal mentioned in the artificial-lake story can suggest a way for you to solve the next task"; then they could pass to the eighth page where they found the target. In the reminding+hint condition, the seventh page reported both the question concerning the mason's proposal (as in the second condition) and the hint sentence (as in the third condition), and the eighth page reported the target. In the reminding, hint and reminding+hint conditions the procedure concerning the target problem was the same as that in the control condition.

The experimenter recorded the responses in each task. Time responses were also recorded. At the end of the experiment, participants were asked: "In your opinion, what was the aim of the experiment?"

Results

In both this experiment and the following experiments, analyses concerning response times failed to show interesting results; therefore they have been omitted. Responses to the target problem were analysed by two independent judges who discussed cases of disagreement to reach a unanimous classification. Judges scored responses in which the dispersion–concentration schema was present as *analogical solutions*. These solutions consisted in sending various weak laser rays by different directions so that they converged on the filament where their combined effect was enough to fuse it.

Frequencies of analogical solvers- that is, participants who gave the analogical solution- under each condition are reported in Table 1. A 2×4 chi-square analysis showed a significant difference in the overall frequencies of analogical and non-analogical responses in each group, $\chi^2(3, N = 80) = 20.07$, $p < .001$. To assess the locus of the frequency differences, 2×2 chi-square analyses were carried out, comparing each condition with the others. Significant differences were found in the following comparisons: control versus hint, $\chi^2(1, N = 40) = 7.29$, $p < .01$; control versus reminding+hint, $\chi^2(1, N = 40) = 10.67$, $p < .005$; reminding versus hint, $\chi^2(1, N = 40) = 5.38$, $p < .05$; and reminding versus reminding+hint, $\chi^2(1, N = 40) = 8.44$, $p < .005$. No significant differences emerged in the following comparisons: control versus reminding, $\chi^2(1, N = 40) = 0.23$, and hint versus reminding+hint, $\chi^2(1, N = 40) = 0.10$.

Responses recorded in the interview at the end of the experiment were classified by the judges according to the kind of aims reported for the experiment. Few subjects (7 out of

Table 1
Frequencies and percentages of analogical solution under each condition of the experiments

Experiment	*Condition*			
1	Control	Reminding	Hint	Reminding + Hint
	2 (10%)	3 (15%)	11 (55%)	13 (65%)
2	Previous Reminding	Concurrent Reminding	Hint	Reminding + Hint
	4 (20%)	2 (10%)	14 (70%)	10 (50%)
3	1-min Oral Reminding	3-min Oral Reminding	5-min Oral Reminding	Hint
	2 (10%)	1 (5%)	2 (10%)	12 (60%)
4	General Reminding	Active Focal Reminding	Passive Focal Reminding	Hint
	0 (0%)	2 (10%)	1 (5%)	13 (65%)
5	Control	Reminding	Hint	
	1 (5%)	2 (10%)	12 (60%)	
6	Control	Reminding	Hint	
	3 (15%)	3 (15%)	10 (50%)	
7	Control	Reminding	Hint	
	3 (15%)	2 (10%)	13 (65%)	

80: 2 in the control, 2 in the reminding, 2 in the hint, and 1 in the reminding+hint condition) realized that the actual aim was to study the transfer of information from a previous task to the target task. Of these individuals, 5 (2 in the control, 1 in the reminding, 1 in the hint, and 1 in the reminding+hint condition) gave the analogical solution to the target problem. The other 73 students did not mention aims related to the analogy; for instance, they said that the experiment was aimed at studying attention, memory, problem-solving, reasoning, intellectual abilities, and so on.

Results suggest that the lack of spontaneous transfer in analogical problem-solving does not depend on failures in the activation of the relevant source information. In fact, although people were invited to recall source information, they did not transpose it to the target in a significantly greater proportion than did those in the control group. Rather, only when subjects become aware of the relationship between source and target can they apply the solution strategy embedded in the source to solve the target problem. This conclusion is supported also by the observation that almost all participants who, irrespective of the experimental condition assigned to them, realized that the purpose of the study was to investigate the effects of a previous task on a subsequent task, caught the source–target connection and gave the analogical solution to the light-bulb problem.

Source activation seems to be beneficial when associated with instructions stressing the source–target relationships, even if the difference between the frequencies of the analogical responses in the hint and in the reminding+hint conditions is not significant. The question about the mason's proposal probably helped participants in identifying quickly the part of the source story that could be mapped onto the target in order to derive the analogical solution.

In conclusion, the data support the notion that the critical process in analogical problem-solving does not consist in *activating* source information just before the target task, but in *realizing* that the source and the target are potentially related. So, it seems that spontaneous transfer fails to occur because of a lack of awareness about the source–target connection.

EXPERIMENT 2

Experiment 1 showed that in the reminding condition few subjects related the critical part of the source to the solution of the target to reach the analogical response. This might have depended on the experimental artefact. In the reminding condition in Experiment 1, participants had to turn the page reporting the question about the source before reading the target problem: This might have induced participants to forget the representation of the source further on. In other words, the short interval between the question about the mason's proposal and the presentation of the light-bulb problem and/or the act of turning the page reporting the question about the source might have yielded the decay of the representation of the source before the target was presented. Thus, participants had to face the target with no previous source information activated in their mind.

To circumvent this, a *concurrent reminding* condition was devised, in which the question concerning the source was presented on the same sheet as the target. We can hypothesize that this induces participants to activate the representation of the source immediately before the target task and that such information is still activated during the target problem because the cue devised for such activation- namely, the question concerning the source- is always available.

In this experiment (concurrent) hint and (concurrent) reminding+(concurrent) hint conditions were included in order to investigate further the effects of the source activation when associated with instructions about the source–target relationship. In Experiment 1 the reminding+hint condition yielded an increase in the percentage of analogical solution when compared to the hint-only condition, even though the difference between the two conditions was not statistically significant. Such a difference might be greater by using a concurrent reminding.

Method

Participants

Eighty undergraduates with different majors were randomly allotted to the following groups: previous reminding, concurrent reminding, hint, and reminding+hint.

Material

The material was basically the same as that in Experiment 1.

Procedure

Participants received a booklet with eight (in the previous reminding condition) or six (in the concurrent reminding, hint, and reminding+hint conditions) pages. Up to the sixth page, subjects were presented with the same tasks in the same order and with the same instructions as in Experiment 1. The previous reminding condition was the same as the reminding condition studied earlier.

In the other conditions, after the presentation of the spy story (first page) and of the puzzle ("How many children . . . ": second page), the question about the spy story was written on the top of the page (the third page) reporting the difference-spotting task. On the fourth page there was the source, on the fifth page the anagram-solving task, and on the sixth page the target problem. In the concurrent reminding, hint, and reminding+hint conditions the text of the problem was preceded, respectively, by the question about the mason's proposal, by the suggestion about the source–target connection, and by both the question and the suggestion.

In all conditions the target problem was presented as in Experiment 1. At the end of the experiment there was, as in the previous one, a short interview about the aim of the experiment.

Results

Protocols concerning the target task and the interview were scored as in Experiment 1. Table 1 shows the frequencies of the analogical solution in the four conditions of this experiment; significant differences emerged, $\chi^2(3, N = 80) = 19.41$, $p < .001$. Chi-square test revealed no significant differences in the distribution of analogical solvers between the first two, $\chi^2(1, N = 40) = 0.78$, and between the last two, $\chi^2(1, N = 40) = 1.67$, conditions. Both in the previous and in the concurrent reminding groups analogical solutions were significantly less frequent than in the hint condition: Respectively, $\chi^2(1, N = 40) = 10.10$, $p < .005$; $\chi^2(1, N = 40) = 15$, $p < .001$; and also less frequent than in the reminding+hint condition: Respectively, $\chi^2(1, N = 40) = 3.96$, $p < .05$; $\chi^2(1, N = 40) = 7.62$, $p < .01$. Frequencies of analogical solvers in the previous reminding, hint, and reminding+hint conditions of Experiment 2 were similar to those recorded in the corresponding conditions of Experiment 1. Moreover, the frequencies of analogical solvers in the previous reminding and concurrent reminding conditions of Experiment 2 were similar to those of the control condition in Experiment 1. In this study, in the reminding conditions, participants neither suspected that the experiment was designed to investigate analogical reasoning nor identified correspondences between the target and the source.

Results of Experiment 2 replicated findings of Experiment 1, namely, that the mere activation of the source information is not sufficient to produce analogical transfer. In the reminding conditions of Experiment 2 nobody realized spontaneously that the artificial-lake story might suggest the solution of the light-bulb problem by analogy. Consequently, as in Experiment 1, being uninformed about the source–target connection, few subjects produced the dispersion–concentration response to the target.

In Experiment 2 we tried to elicit the memory of the source immediately before and, possibly, during the target task. To do so, we designed a procedure that prevented

subjects from turning the page reporting the reminding question. In this way, subjects would not be induced to discard source information activated by such a question before facing the target. Nevertheless, spontaneous analogical solutions were unlikely to occur.

In this experiment the simultaneous presentation of the reminding and of the hint failed to improve analogical transfer in comparison to the hint alone. Thus, we cannot maintain, as previously hypothesized, that reminding (even if it is not sufficient to favour the solution by analogy of the target) has a facilitating effect when associated with information about the source–target connection.

EXPERIMENT 3

Experiment 2 showed that concurrent reminding was ineffective in suggesting the analogical solution to the target problem. This might occur because participants engaged in the solution of the target were deeply involved in the task, so that they paid no attention to the cue printed on the top of the page and, consequently, there was not the concurrent activation of the source. We can hypothesize that although the question concerning the mason's proposal was always available, participants read it before facing the light-bulb problem but then discarded it immediately.

In order to "compel" subjects to activate (though temporarily) the source during the target phase, in Experiment 3 the question about the critical part of the source was asked while subjects were looking for the solution to the target. In this way, to answer the source question, subjects had to stop thinking about the target and retrieve the source, which consequently should just have been activated during the attempts to solve the light-bulb problem.

In order to yield the activation of the memory of the source during the solution of the target, the question of *when* to produce such activation arises. In fact, too early an activation of the source may be ineffective because subjects are still reading the text of the target and so cannot relate such information to the light-bulb problem, which at that moment is not completely represented in their minds. We may suspect that hints may be effective only when they are presented after subjects have spent some time trying to solve the target. On the contrary, too late an activation may fail to influence problem-solving because subjects are already following a well-established direction in reasoning and are going on with responses involving the same assumptions, so that they are not sensitive to the cue provided by the source question. These conjectures led us to introduce the experimental manipulation aimed at activating source information (namely, the question about the mason's proposal) at different moments- that is, after participants were presumed to have read the target, while they were attempting different approaches to the problem, and after they had no further idea about how to solve it.

Method

Participants

Eighty university students were randomly assigned to the following groups: 1-min oral reminding, 3-min oral reminding, 5-min oral reminding, and hint.

Material

The same tasks as those in Experiment 2 were employed.

Procedure

For all the reminding conditions the procedure was the same as that in the concurrent condition of Experiment 2, with the exception that the questions about the spy story and the mason's proposal were not written but were orally presented by the experimenter while participants were engaged, respectively, in the visual matching task and in the target problem-solving task. In the first condition the experimenter asked the question after 1 min from the beginning of the task; in the second condition this happened after 3 min, and in the third condition after 5 min. The hint condition was the same as in Experiment 2, but the experimenter gave the cue about the source–target connection orally 1 min after participants began reading the light-bulb problem.

Results

The same procedure as that in Experiment 1 was employed to analyse participants' responses to the light-bulb problem and in the interview.

Frequencies of analogical solution are described by Table 1; a chi-square test analysis indicated that differences among the conditions are significant, $\chi^2(3, N = 80) = 24.13$, $p < .001$. No significant differences in the frequencies of analogical responses among the three reminding conditions emerged, $\chi^2(2, N = 60) = 0.44$, nor between each of these conditions and the control condition of Experiment 1: Respectively, $\chi^2(1, N = 40) = 0$; $\chi^2(1, N = 40) = 0.36$; $\chi^2(1, N = 40) = 0$. Distributions of analogical solvers in the reminding conditions of Experiment 3 were approximately the same as those in the reminding conditions investigated in Experiments 1 and 2. No one achieved the goal of the experiment. In the hint condition of Experiment 3 the frequency of analogical solvers was similar to that recorded in the corresponding conditions of Experiments 1 and 2 and was significantly higher than that recorded in each of the oral reminding conditions: Respectively, $\chi^2(1, N = 40) = 10.98$, $p < .001$; $\chi^2(1, N = 40) = 13.79$, $p < .001$; $\chi^2(1, N = 40) = 10.98$, $p < .001$.

Also Experiment 3 failed to support the notion that the activation of the source without awareness of the source–target relationship facilitates analogical problem-solving. In Experiment 3 the source was activated by an oral cue instead of, as in Experiment 2, a written cue, and such a cue was provided in three different moments of the target task. However, also in this case few subjects showed spontaneous transfer. The recall of the relevant source information during the target task was ineffective both when the cue was given at the beginning of the reasoning process and when it was given during or after a longer involvement in the target task. As inviting subjects to recall information necessary for the solution of the target problem in all the three distinct moments of the problem-solving process did not increase rates of analogical responses as compared to a control condition where such a cue was not given, we are induced to conclude that the critical element that impedes spontaneous transfer in solving a problem by analogy is realizing that source information is related to the target situation and not activating source memory during the target problem.

EXPERIMENT 4

Previous experiments showed that reminding alone did not induce people to relate the source to the solution of the target. However, it might be argued that participants did not reach the analogical response because the reminding instructions were too general and not sufficiently focused on the elements of the source that were relevant to the solution of the target. Furthermore, in the reminding conditions the effort to recall the source information might have interfered with its possible subsequent utilization in solving the target.

To obviate this, in Experiment 4 we designed different kinds of reminding: an *active general reminding*, in which participants were asked to repeat what they could remember about all the previous tasks; an *active focal reminding*, in which they had to explain the mishaps of the engineer's plan and the advantages of the mason's suggestion; a *passive focal reminding*, in which they had to read a summary of the artificial lake story stressing the aspects useful to solve the light-bulb problem analogically. We hypothesized that in the last two conditions participants had to pay more attention to the critical elements of the source and, consequently, activated a highly focused memory of the isomorphic aspects. The conjecture that mental work needed to retrieve the source may inhibit its transfer to the target was tested through the comparison between the active and passive reminding conditions. The *hint* condition was the same as that in Experiment 1.

Method

Participants

Eighty university students were randomly allotted to the four conditions of the experiment.

Material

The material was the same as that in Experiment 1.

Procedure

Participants received a booklet with eight pages. Up to the sixth page, participants were presented with the same tasks in the same order and with the same instructions as in Experiment 1. The seventh page reported the following instructions, which were different in each condition. The general reminding group was asked: "Relate what you recall about the content of the tasks you have carried out till now"; in the passive focal reminding condition participants were asked to read again the paragraphs of the source story in which the mason's proposal was described; in the active focal reminding participants were told: "In the artificial-lake story, what mishaps of the engineer's plan did the mason stress, what did he suggest, and what were the advantages of his proposal?" For the hint group instructions were the same as those in Experiment 1.

In all conditions the target problem was presented as in Experiment 1 on the eighth page. At the end of the experiment there was a short interview about the aim of the experiment.

Results

Protocols of the target task and of the interview were analysed as in the previous experiments. Frequencies of analogical solvers under the four conditions of the experiment are reported in Table 1. Significant differences in the distribution emerged, $\chi^2(3, N = 80) = 34.37$, $p < .001$. In the hint condition analogical solvers were significantly more frequent than in each of the reminding groups: Respectively, $\chi^2(1, N = 40) = 19.26$, $p < .001$; $\chi^2(1, N = 40) = 12.91$, $p < .001$; $\chi^2(1, N = 40) = 15.82$, $p < .001$. No significant differences among the three reminding groups emerged, $\chi^2(2, N = 60) = 2.11$. Frequencies of analogical solutions in the reminding conditions investigated in this study were similar to those recorded in the other reminding subsamples of the previous experiments and were not significantly different from those recorded in the control group of Experiment 1: Respectively, $\chi^2(1, N = 40) = 2.11$; $\chi^2(1, N = 40) = 0$; $\chi^2(1, N = 40) = 0.36$. The final interview showed that no one realized that the source and the target were related.

In this experiment we tried to focus the activation of the source only onto the elements relevant to the solution of the target. However, even in this case reminding was not effective in improving analogical transfer. Furthermore, neither simply reading the summary of the critical points of the source nor the effort to recall them induced subjects to apply the solution principle embedded in the artificial lake story to the light-bulb problem. In fact, in both cases percentages of analogical solvers were not significantly higher than those produced by a general reminding of all the material to which subjects were exposed during the experiment.

EXPERIMENT 5

Experiments 1–4 showed that the solution principle embedded in a source story can be applied to an isomorphic target problem of a different domain only in presence of the awareness of the source–target connection. In fact, in these experiments the mere activation of the source- even though the person's attention was focused only on the relevant information- immediately before or during the target task had no effect in enhancing analogical transfer unless it was accompanied by a hint that induced the subject to search for possible source–target similarities.

In Experiments 1–4 the source and the target were semantically unrelated. Keane (1987, Experiment 2) found that if in the target problem an instrument that is identical or semantically similar to the corresponding element of the source is mentioned, a considerable percentage of participants can retrieve the source before or during the target task.[5] This led us to wonder whether, without hints, the inclusion of such an element in the source favours the analogical solution of the target problem owing to the pure activation of the source itself. In order to answer this question a new line of investigation (Experiments 5–7) was undertaken. More precisely, in Experiment 5 laser rays[6]- that

[5] However, as noticed previously (see Footnote 1), subjects were given implicit hints. This can explain differences between Keane's (1987) results and data of Experiments 5–7 reported here.

[6] In Italian it is not possible to use the word "laser" alone; it always has to be followed by the word "ray". Furthermore, there are not two distinct words for "ray" and "beam": Both are translated by the same word ("raggio"). This explains why we could not distinguish- as Keane (1987) did- between an identical (ray) and a semantically close (laser) element or between an identical (ray) and a related (beam) word.

is, the instrument used to solve the light-bulb problem- were also mentioned in the source story. Such a revised story was presented in a control, reminding, and hint condition.

Method

Participants

Sixty university students were randomly assigned to the three conditions of the experiment.

Material

The material was the same as that in Experiment 1. However, in the source the following sentence, "A laser-ray system was devised to monitor the stream of water into the lake so that it would detect both overflowing and insufficient feeding", was included between the sentence "These small canals were placed . . ." and the sentence "In this way only small amounts . . . ." Furthermore, in the story the mason was substituted by a technician, a character who is more likely to operate the laser-ray device.

Procedure

In the control, reminding, and hint conditions the order of presentation of the tasks, the instructions, and the time allowed were the same as those in the corresponding conditions of Experiment 1. In the reminding condition, the sheet preceding the target problem reported this question: "In the artificial-lake story, what mishaps of the engineer's plan did the technician stress, what did he suggest, and what were the advantages of his proposal?" In Experiment 5, as in the others, there was a final interview about the purposes of the study.[7]

Results

Percentages of analogical solvers under each condition are reported in Table 1. Significant differences in the distribution were found, $\chi^2(2, N = 60) = 19.73$, $p < .001$. The number of analogical solvers was significantly higher in the hint condition than in the control, $\chi^2(2, N = 40) = 13.79$, $p < .001$, and reminding, $\chi^2(2, N = 40) = 10.98$, $p < .001$, conditions. In the reminding condition the number of analogical solvers was not significantly higher than in the control condition, $\chi^2(2, N = 40) = 0.36$. Percentage of analogical responses in the control and reminding conditions in Experiment 5 were similar to those recorded in the corresponding conditions in Experiment 4 where laser rays were not mentioned in the source story. Thus, if an explicit hint was not provided, the presence of the same elements (laser rays) both in the lake story and in the light-bulb problem did not lead participants to notice source–target correspondences.

[7] In Experiments 5, 6, and 7 nobody realized the real aim of the tasks; thus, analyses concerning the final interviews were not reported.

EXPERIMENT 6

It might be argued that in the revised version of the source story employed in Experiment 5 the introduction of an element (ray) semantically identical to the corresponding element of the light-bulb problem had no effect because the laser ray played an irrelevant role in the artificial-lake story and, consequently, it was likely to be neglected. Therefore, in Experiment 6 the text of the source was changed again so that the laser rays became more crucial and were linked to the central problem of that situation, namely, the need to prevent both overflowing and insufficient feeding.

Method

Participants

Sixty undergraduates were randomly distributed among the control, reminding, and hint conditions of the experiment.

Material

The material was the same as that in Experiment 5, except that the sentence added to the source story in Experiment 5 was extended as follows: "A laser-ray system was devised to monitor the stream of water into the lake so that it would detect both overflowing and insufficient feeding. More precisely, a laser beam, set at the highest possible water level, would be deactivated if the water rose any higher. Another laser beam, set at the lowest possible water level, would be activated if the water fell under that level."

Procedure

The procedure was the same as that in Experiment 5.

Results

Table 1 reports frequencies of analogical solvers in the control, reminding, and hint conditions. Analogical solvers were distributed in significantly different rates under the three conditions, $\chi^2(2, N = 60) = 8.35$, $p < .05$. Analogical solvers were more frequent in the hint condition than in the control and reminding conditions, $\chi^2(2, N = 40) = 5.58$, $p < .05$. Also in this case the reminding condition failed to increase analogical transfer as compared to the control condition.

EXPERIMENT 7

In the source story employed in Experiment 6 the laser-ray system, though included in the core issue of the artificial-lake situation (that is, the overflowing/insufficient flowing of water), had no relation to the dispersion–concentration solution. In fact, in that story the laser beams worked only as a detector device and had no direct effects on modifying the stream of water in order to prevent the two mishaps (overflowing and insufficient feeding). This might reduce the salience of laser rays as tools linked to the idea of dividing

the unique wide stream of water into small canals coming from different directions and to the summation of small amounts of water conveyed by these canals into the lake. Thus, a new version of the artificial-lake story was devised so that the element of the source (laser beam), that was superficially similar to the corresponding element of the target played a notable function both in the control of the water streams and in the solution of the problem risen by overflowing and insufficient feeding. The purpose of Experiment 7- where the same design as that in Experiments 5 and 6 was employed- was to assess whether reminding a source story in which the critical element shared by the target had a remarkable role was effective in inducing spontaneous analogical transfer.

Method

Participants

Sixty university students were randomly assigned to the control, reminding, and hint conditions.

Material

The same source story as that in Experiment 6 was employed. However, the new part included in Experiment 6 was now enlarged as follows: "A laser-ray system was devised to control and monitor the stream of water conveyed into the lake so that it would detect and solve overflowing and insufficient feeding problems. More precisely, a laser-ray emitter was located in correspondence with each canal. This emitter would send rays to a station in the centre of the lake signalling how much water was conveyed by the canal at that moment. The station would sum up signals coming from the four canals. On the basis of the resulting whole signal the station would give the order either to reduce the stream of water (if excessive) or to increase it (if insufficient)."

Procedure

The procedure was the same as that in Experiment 6.

Results

Frequencies of analogical solvers under the three conditions were significantly different, $\chi^2(2, N = 60) = 17.62$, $p < .001$. The number of analogical responses in the hint condition was significantly higher than in the control, $\chi^2(1, N = 40) = 8.45$, $p < .005$, and in the reminding condition, $\chi^2(1, N = 40) = 10.67$, $p < .005$, which did not differ significantly, $\chi^2(1, N = 40) = 0.23$. Thus, even if the artificial-lake story included an element that was superficially similar to a corresponding element of the target problem, and such an element was involved in the dispersion–concentration strategy described in the source, reminding source information very close to the target task did not prompt the transfer of the solution strategy to the light-bulb situation as the explicit hint did.[8]

[8] The reduced impact of the superficially similar element might depend- as suggested by an anonymous referee- on the fact that it does not play the same role in the source and in the target situations, so impeding a perfect relational match between the two analogs.

Considered together, Experiments 5–7 showed that no spontaneous transfer occurred as a consequence of the immediately previous activation of the source, even though the source and the target shared identical elements and the salience of these elements was progressively increased so much that they were deeply involved in the solution schema (the dispersion–concentration principle) underlying both the source and the target.

GENERAL DISCUSSION

The present investigation addressed the issue of the lack of spontaneous transfer in analogical problem-solving reported by several previous studies. The purposes of our experiments were: (1) to distinguish between the role of activating relevant information previously given and of connecting such information to the target task; (2) to give a more accurate description of the access phase of analogical problem-solving; and (3) to consider some implications for theoretical models of analogical problem-solving.

In the earlier experiments, in order to find the solution of a target problem, participants were invited, by means of a "hint", to make use of the previously presented information. Such a hint had the effect of inducing subjects both to recall source information and to relate it to the target and so did not enable us to ascertain whether the lack of transfer that emerged in participants who were not given a hint was due to the lack of recalling or of relating. Our experiments were devised to compare situations in which only the activation of the source occurred to situations where participants were informed about the relationships between the source and the target (without or together with the activation of the source).[9] Results showed that the simple activation of the source information relevant to the solution of the target does not yield a significant increase in analogical responses as compared to control conditions where neither reminding instructions nor hints were given.

Before attempting to explain our findings, some possible criticisms must be considered. First, one can argue that people do not spontaneously transfer information from the source to the target because they fail to remember the source while attempting to solve the target. However, there is evidence that, if people are asked to recall the source after the target task, they do so correctly and completely (Gick & McGarry, 1992; Novick & Holyoak, 1991), and also participants in our experiments, when requested (in the reminding conditions) to recall the critical part of the artificial-lake story, always retrieved the source adequately. In addition, even if there was no reason to suspect that memory failures intervene to prevent spontaneous transfer, our subsequent experiments were devised to circumvent such effects. More precisely, Experiments 2 and 3 were designed to falsify the findings of Experiment 1 by trying to activate the source in the same setting as that of the target and closer and closer to the target itself, in order to avoid the representation

[9] In our experiments percentages of analogical solutions in the conditions were lower than in earlier experiments presumably because- as suggested by an anonymous reviewer of our paper- there are some dissimilarities between the artificial-lake story and the light-bulb problem. In fact, the water in the lake story is analogous both to the laser ray and to the filament in the target problem. This potential many-to-one mapping might decrease rates of analogical transfer because it has been argued that people do not map sources and targets unless there are more than just one-to-one isomorphisms (Gentner, 1983).

of the source activated by the question about the mason's proposal decaying or subjects not paying attention to it while solving the light-bulb problem. Also in such experiments the mere activation of the source, elicited immediately before or during the target task, was ineffective in enhancing analogical solutions, and even a passive focused activation of the memory of the source, as shown by Experiment 4, failed to prompt analogical transfer.

Second, Bowden (1985) maintains that individuals not given a hint can utilize previously acquired information if the experimental procedure does not impose time constraints, so that they are allowed sufficient time to search the relevant information. However, in our experiments, participants in the reminding conditions had enough time to search for some clues useful to the solution of the target in the information acquired earlier. Moreover, in our experiments, reminding instructions, as well as hint instructions, invited participants to pay attention to a limited set of information presented in the source so that differences in the two kinds of conditions would not arise from differences in the amount of potentially relevant knowledge that subjects were to examine. In other words, in comparison with the no-hint manipulations, facilitating effects of the hint do not seem to consist in restricting the problem space in which subjects can search for the solution.

Third, the lack of spontaneous transfer might depend on the fact that subjects did not consider, in the acquisition phase, aspects of the source that are relevant to the solution of the target (Stein, Way, Benningfield, & Hedgecough, 1986). However, in the focal reminding conditions of Experiment 4 the participants' attention was addressed explicitly toward the elements of the analogical story that were structurally similar to the dispersion–concentration solution of the light-bulb problem- that is, on the relevant element. Furthermore, this element, as emerged from responses given to the active reminding question that preceded the target presentation, was adequately encoded and managed to be correctly recalled.

Finally, the experimental procedure usually employed in studying analogical problem-solving might be considered as inappropriate because it might artificially induce subjects to perceive the target as separate from the source (Catrambone & Holyoak, 1989). In fact, the interviews carried out at the end of each experiment showed that all (Experiments 2, 3, and 4) or almost all (Experiment 1) the participants did not realize that there was a link between the two tasks that they had performed. However, we can remark that in everyday life, in cases where analogical reasoning occurs, the target situation in which past experience may be useful does not usually immediately follow source presentation. Furthermore, in common life occurrences there are no external aids to tell us of some previous experience that, because of differences in the domain and context of acquisition, we do not perceive as being similar to the current task. So, the experimental procedure employed in this study seems to mirror, even though it involves some obvious simplifications, common situations in which we encounter source information that, after various interpolated events, may be transposed to a subsequent target problem.

After having discarded some possible criticisms, we can draw our attention to possible implications of our results for the access phase of analogical problem-solving. On the basis of our data we can conjecture that analogical problem-solving requires, after the encoding of the source, source information to be present in the person's mind when he or she is attempting to solve the target. Such an activation may be elicited automatically by stimuli

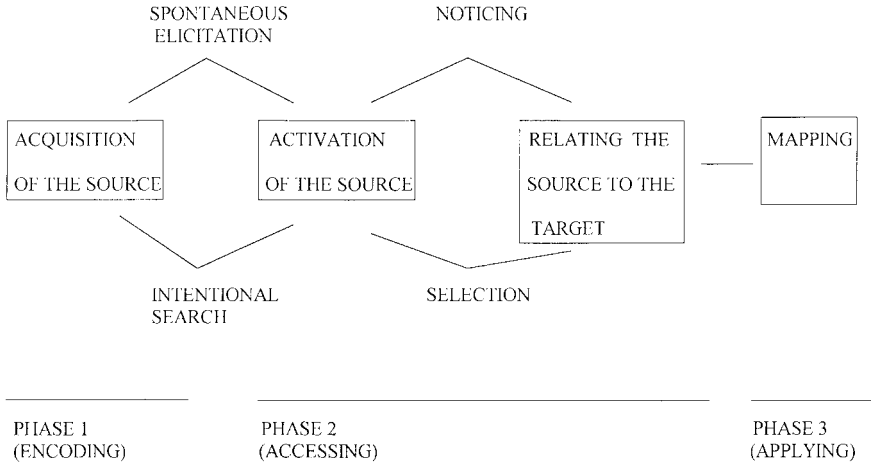

Figure 1. Schematic depiction of the two-subphases model of analogical problem-solving.

embedded in the target setting or by an intentional search in memory. In any case, individuals must realize that the activated information can be related to the target task because such information may be useful to its solution. This may happen either as a consequence of events that produce such an awareness or as a consequence of an intentional selection of the activated source information in order to identify which elements are relevant to the target. When subjects have realized the source–target connection, they can map the source onto the target to transfer the solution procedure described in the source to the novel problem by means of matching operations. Figure 1 schematizes this process.

With this description of the access phase in mind, we can try to give an overall interpretation of the results of the experiments. The lack of spontaneous transfer can be accounted for by two distinct explanations (Perfetto et al., 1983). First, subjects may have not retrieved the source information while solving the target. Alternatively, subjects may have retrieved the appropriate information when they were working on the target, but discarded or ignored it as irrelevant because they did not perceive it as appropriate to the target (see also Needham & Begg, 1991; Stein et al., 1986). Perfetto et al. (1983) argue that the non-hinted participants' failure to use the source is not due to the fact that they actually retrieve the appropriate information even if then they fail to recognize the relevance of such information to the target. By contrast, our findings support the second explanation because they demonstrate that retrieving the source immediately before or during the target problem task does not produce notable advantages in comparison with a control condition where subjects are simply exposed to the source. Therefore, we are induced to accept that recognizing the appropriateness of the source information, but not retrieving it, is the crucial aspect in spontaneous transfer. Some studies reviewed in the Introduction showed that, under certain circumstances, superficial similarities between source and target helped subjects in solving the latter on the basis of the solution principle embedded in the former, but this occurred only when there was a blatant connection between the source and the target (such as when there was a very high degree of superficial similarity: see Reeves & Weisberg, 1994).

In conclusion, it seems that analogical problem-solving is not an automatic process, but it requires controlled attempts to relate the target to a prior source. If we were to introduce a well-established distinction, we could say that top-down rather than bottom-up mechanisms underlie analogical problem-solving. Transfer from the source to the target does not appear to be data driven: Sources sharing common elements with the target also fail to induce spontaneous utilization of the principles embedded in the source for the solution of the target. The source–target linkage is grounded not on "natural" affordances emerging from the material given, but on the awareness of the potential similarities existing between two remote domains, which induces the search for structural, not obvious, correspondences between them. In other words, a strategic attitude is needed to solve a new problem by taking advantage of isomorphic information acquired previously.

These findings cast doubt on the psychological reality of some theoretical models of analogical problem-solving. Our data showed that activation is not the critical process. Mere activation is ineffective unless people realize the source–target connection. This awareness does not seem to derive from a summation mechanism.

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APPENDIX A

The light-bulb story employed as target

In a university lab. a very expansive light bulb, which would emit precisely controlled quantities of light, was being used in some experiments. One morning the research assistant responsible for operating the sensitive light bulb came into the lab. and found to her dismay that the light bulb no longer worked. She realized that she had forgotten to turn it off the previous night. As a result the light bulb overheated, and the filament inside the bulb had broken into two parts. The surrounding glass bulb was completely sealed, so there was no way to open it. The light bulb could be repaired if a brief, high-intensity laser ray could be used to fuse the two parts of the filament into one. Furthermore, the lab. had the necessary equipment to do the job. However, a high-intensity laser ray would also break the fragile glass surrounding the filament. At lower intensity the laser ray would not break the glass, but neither would it fuse the filament. So it seemed that the light bulb could not be repaired. How could you solve this situation?

APPENDIX B

The artificial-lake situation employed as source

An engineer had to plan the construction of an artificial lake to produce electric energy. To feed the lake he thought to build a unique wide canal collecting water coming from a near valley. However, a mason pointed out that during the flood periods the stream of water flowing along the canal might be too strong and might damage the surrounding areas; by contrast, during the drought periods a unique stream of water might be insufficient to feed the lake. In order to avoid these mishaps, the mason suggested to build,

instead of a unique wide canal, four small canals whose total flow was the same as the unique wide canal previously planned. These small canals were placed around the lake so that they conveyed water coming from four different valleys. In this way only small amounts of water could flow in each canal and thus during flood periods dangerous overflowing might not occur. At the same time, the lake was fed by water from various belts, so that also during drought periods it was sufficiently fed.