9

Contraries in productive thinking

Branchini E.* - Burro R.** - Savardi U.***

9.1 Premise

In this chapter we deal with the mental processes involved in "problem solving" which may include a variety of cognitive functions such as insight, memory processes, past experience, new information requiring the use of additional processes of elaboration or mental sets. We hypothesize that contrariety plays a role in this process. In fact, if contrariety is not only an "abstract" relationship linking two concepts but may also characterize the relationship perceived between configurations or parts of configurations (Bianchi & Savardi, 2008; Savardi & Bianchi, 2000), then it may be a fundamental part of the processes involved in understanding the structure of a problem and searching for a solution. We propose an initial test of this hypothesis by analyzing the structure of 10 traditional problems. We will then refer to two studies which were conducted to test the hypothesis further.

9.2 What is problem solving?

In the field of psychology, various definitions have been proposed. Some psychologists think that problems are characterized by the presence of a strong impulse to find a solution and by the lack of an immediate solution (Mowrer, 1947). To put it in another way, problems arise when individuals have an aim and their first attempt to achieve this aim leads to failure (Van de Geer, 1957). Similarly, for Duncker (1969) and Kanizsa (1973), a problem is a situation in which a living being has a goal that she/he wants to reach, but she/he does not know how. According to

* Graduated in Educational Sciences, University of Verona. E-mail: erika.branchini@gmail.com
** Assistant Professor in General Psychology, Department of Psychology and Cultural Anthropology, University of Verona. E-mail: roberto.burro@univr.it
*** Full Professor in General Psychology, Department of Psychology and Cultural Anthropology, University of Verona. E-mail: ugo.savardi@univr.it

Newell and Simon, a problem arises when a person wants something but does not know what actions are necessary to achieve their goal (Newell A., Simon H.A., 1972). For Claparède (1972), a problem consists of environmental conditions that cause an imbalance which needs to be addressed. Bartlett (1975) considers that problems are caused by situations in which some information is missing. Dewey focuses on subjective experiences and states that a problem occurs when a person experiences a sensation of difficulty (Dewey, 1910). Some invariant aspects characterizing problem solving emerge:

1. a problem is a situation that is not solvable by means of common learning processes;
2. the solution cannot be reached simply by reactivating a procedure already used in the past;
3. the solution is not reached by means of automatic prearranged procedures.

It is thus clear that novelty and lack of familiarity are inherent features of problems. As a result of this, the mechanical application of previously learnt methods is not always successful and new strategies are required.

Many authors have linked problem solving and various types of thinking. Guilford (1968; 1971) suggested that convergent thinking and divergent thinking are fundamental: the former is present when there is only one correct solution; the latter is involved when more than one solution is possible. Another author who directly connected problem solving to reasoning is Sternberg (1987). More specifically, he related it to inductive and deductive reasoning. Inductive reasoning is involved in the solution of problems with an inductive structure. Analogies, completions of series and classifications are included in this class. Deductive reasoning is used in the solution of problems that have the form of linear, categorical and conditional syllogisms. Johnson Laird (1994) focused on another ability used in problem solving which is also related to certain mental processes involving reasoning: creativity. This refers to the capacity to generate something new beginning from the elements or information characterizing a given situation. According to Johnson Laird, it includes the following features:

1. it is a process that begins with existent elements but involves new combinations;
2. it satisfies some pre-existent principles;
3. it is not the result of deterministic procedures.

Novelty is something which has been highlighted by many cognitive scientists, not only Johnson Laird. Both Guilford and Sternberg consider that it is not sufficient to use already applied strategies and it is necessary to make use of new mental processes since the solution is not necessarily the exact reproduction of a previous one (Guilford, 1971; Sternberg, 1987). Novelty is also at the heart of all creative work according to Mouchiroud & Lubart (2001). And in fact problem solving and creativity have some characteristics in common: in addition to novelty and originality, both processes require flexibility which means being willing to change a strategy when it fails (Deák, 2000). Another aspect that the two processes have in common is fluency which refers to the quantity of ideas that a person is able to produce when facing a problem. Individuals with a wide range of knowledge are considered to be more inclined to generate a greater number of potential solutions (Batey & Furnham, 2006).

In effect, memory plays a very important role in problem solving, since it allows better coding of the inherent features of a problem and their links with stored information (Antonietti, 2001).

The tendency to solve problems in a fixed way, based on previous solutions to similar problems, is defined as a mental set (Öllinger, Jones & Knoblich, 2008). It has been shown that the use of previously learnt strategies facilitates the solution of problems requiring the application of analogy (Antonietti, 2001) but can be an obstacle when other types of problems are considered (Öllinger et al., 2008). When a problem is similar in appearance to one that has been previously encountered, there may be a tendency to apply the same procedure and this may lead to failure. Sherman and Bisanz (2009) have emphasized the importance of children fully understanding what they learn in order to avoid the blind, mechanical application of strategies already applied in the past to new circumstances.

The fact that total comprehension is an important pre-requisite to finding the best solution to a problem was also emphasized by Wertheimer when referring to productive thinking (Wertheimer, 1965). According to him, productive thinking is the kind of thinking which is involved when a person reaches full understanding of the real structure of a problem. This in turn activates a restructuring process which consists of a series of unions and separations of the elements of the problematic structure. If "contrariety is directly perceivable as a relationship between events/objects or properties" (Bianchi & Savardi, 2008, p. 144), it is also possible to put forward the hypothesis that these operations imply contrariety.

With this in mind, we tested whether, when comparing the original structure of a problem and its solution, contrariety emerges as a key relationship. Although Wertheimer did not specifically mention this, we hypothesized that elements with a specific aspect in the problematic situation have in most of the cases an opposite aspect in its solution.

9.3 Ten classic problems

In order to test the hypothesis that the process of re-structuring implies the transformation of certain aspects of the initial situation into their contraries, we analyzed the structure of 10 classic problems which are often cited in Psychology texts on problem solving. For each problem we defined the problematic situation and its solution and identified the relationship of contrariety between elements of the original situation and elements of the solution.

We decided to start our analysis with Wertheimer's problems (Wertheimer, 1965) since he is said to have been the first to pay attention to the elements making up the perceptual or represented structure of a problematic situation. In the parallelogram problem, as we can see from Table 9.1, people are asked to find the formula to calculate the area of a parallelogram and to demonstrate why it is correct (Figure 9.1). The solution is to transform the parallelogram into a rectangle, i.e. an unstable, "leaning" shape, is "straightened up" and thus becomes a stable, "upright" shape.

Table 9.1 Ten classic problems, presented by author, year, classification of the type of problem, aim of the problem in the original work presenting it, exact formulation of the problem and solution. The last column shows which elements of the problems are transformed into a contrary aspect in the solution.

N	Author	Year	Type of problem	Aim of the problem	Formulation	Solution	Contraries
1	Wertheimer	1965	geometric	To verify full comprehension of the problem	Find the formula to calculate the area of parallelogram and demonstrate the procedure	Change the parallelogram into a rectangle	Irregular and dynamic figures-regular and stable figures; left-right; interior lines-exterior lines
2	Wertheimer	1965	spatial- logical	To verify the abilities of deaf children.	Create a bridge with three oblong shapes	Place the two oblongs of the same length vertically and the third on top horizontally	Same length-different length; vertical-horizontal; up- down; left- right
3	Wertheimer	1965	geometric	To verify full comprehension of the problem	Demonstrate the equity of the vertically opposite angles	See the two vertically opposite angles as a part of the same straight angle	Up- down; left- right; whole- part
4	Wertheimer	1965	geometric	To verify full comprehension of the problem	Demonstrate that the sum of the angle of a polygon is always the same	See the link between the shape of the figure and the angles created	Inside-outside; left-in the centre-right; central role-secondary position
5	Katona	1972	geometric	To verify the role of training	Transform the five squares into four squares of the same size moving only three matches	Move three matches from down to up; elimination of two squares and creation of one square	Up-down; elimination; creation
6	Kanizsa	1973	spatial-geometric	To verify the role of habits	Create a square using six figures: four identical isosceles triangles and two trapeziums of the same height but with unequal bases	Contrast the normal disposition of the figures	Separate elements-whole figure; equal-unequal; top-bottom; vertical-oblique-horizontal;

continue

Table 9.1 Ten classic problems, presented by author, year, classification of the type of problem, aim of the problem in the original work presenting it, exact formulation of the problem and solution. The last column shows which elements of the problems are transformed into a contrary aspect in the solution (continued).

N	Author	Year	Type of problem	Aim of the problem	Formulation	Solution	Contraries
7	Kanizsa	1973	geometric	To verify the role of perception	Calculate the area of a figure made up of a parallelogram and a square	Realize that the figure is made up of two triangles and multiply the bases of the square by the side PD (see figure 7)	Two triangles: one pointing up and the other pointing down; part-whole; in front of - below organization
8	Maier	1931	spatial-geometric	To verify the role of internal direction in reasoning	Connect the nine points with four segments of straight lines without detaching the pencil from the sheet and without passing twice over the same point	Move away from the perception of a closed figure that the nine points seem to create and use the exterior space	Closed figure-open figure; inner space-exterior space
9	Maier	1931	logical	To verify the role of functional fixity	Two cords hanging from the ceiling have to be tied together but cannot actually be held in the hands at the same time	Contrasting the normal function of pliers: they must to be used as a pendulum to join the two cords	Two separate elements-two joined elements; tools for cutting and bending - tools for joining; weight-lightness
10	Harrower	1932	spatial- logical	To verify the role of mental images	Two ducks in front of two other ducks, two ducks behind two other ducks, two ducks in the middle. They swim under a bridge. How many ducks are there?	Vertical disposition of the pair and horizontal disposition of the bridge; the total number of ducks is four	In front of-in the middle-behind; vertical-horizontal

This change is produced by drawing two perpendicular lines from the A and B vertexes. In this way two identical triangles are formed, one on the left, inside the parallelogram, and the other on the right, outside the parallelogram. By moving the left hand triangle (which appears to be outside the rectangular shape and is thus "in excess") to "fill in" the triangular area on the right which appears to be "missing" from the rectangle, we obtain a regular rectangle, and the area can now be calculated in the normal way.

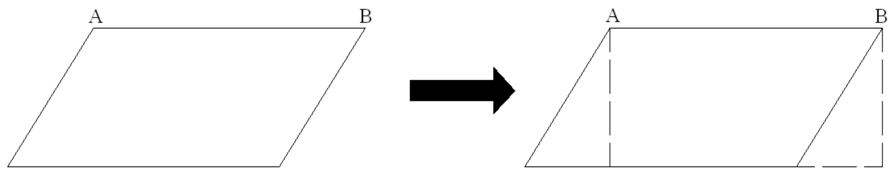

Figure 9.1 The parallelogram problem (problem 1, in Table 9.1): initial configuration and its solution.

The second problem involved creating a bridge using three oblong shapes, two of the same length and the other longer (see Figure 9.2, the diagram on the left). The solution was to position these shapes in a different way in order to form a bridge. Various aspects of contrariety are present: to reach the solution it has to be understood that the structure of the bridge is based upon contrary properties, i.e. the two shorter rectangles have to be positioned vertically while the longer one (which is vertical in the initial configuration) has in contrast to be positioned horizontally (see Figure 9.2, diagram on the right). There are contraries in the following pairs: short-long, same length - different length; vertical-horizontal.

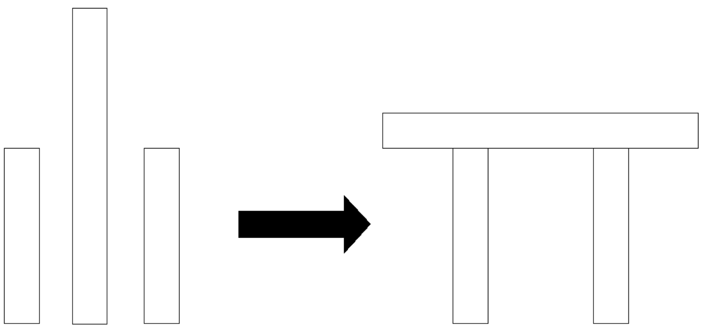

Figure 9.2 The bridge problem (problem 2, in Table 9.1): initial configuration and its solution.

The third problem is the opposite angles problem (Wertheimer, 1965). The task is to demonstrate that the angles x and y in Figure 9.3 are equal.

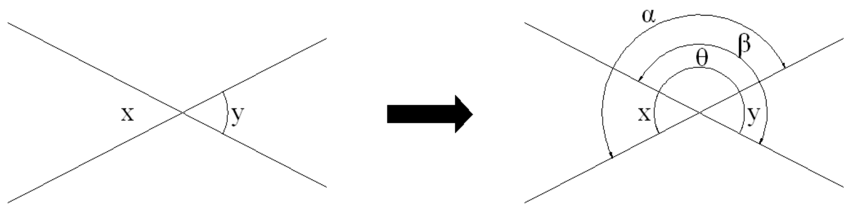

Figure 9.3 The opposite angle problem (problem 3, Table 9.1): initial configuration and its solution.

The four angles created by the two diagonal lines are opposites in terms of left-right, and up-down. To reach the solution, it is necessary to perceive the relationship between the angles linked by the same straight line which have an angle in common (θ) – see Figure 9.3, the diagram on the right. The straight line forms a straight angle (α) that is formed by joining together angle x and angle θ. The same holds for angle y and angle θ which together create angle β (see Figure 9.3, the diagram on the right). Therefore angle x is part of the angle α and can be measured by subtracting angle θ from 180°. The same applies to angle y . To reach this solution one needs to work on the part-whole organization of the initial configuration: it is necessary to consider the angles x and y not as separate elements but as parts of a bigger angle formed by each diagonal.

A fourth problem that we considered concerns the sum of the outside angles of a polygon (Wertheimer, 1965).

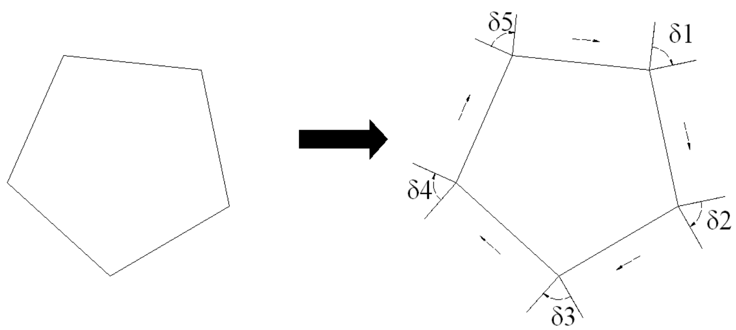

Figure 9.4 The sum of the angles of a polygon (problem 4, Table 9.1): initial configuration and its solution. The outside space around each angle is divided in two right angles and a rotational angle (δ) in between.

The solution to this problem requires relating the angles on the inside of the shape with the angles are created around its exterior (Figure 9.4). The extended contour line creates two opposite spaces, one inside the contour and the other outside. Three outside angles are formed in each vertex: a right angle on the left, a δ (rotational) angle in the centre and another right angle on the right. The sum of the right angles is easy to calculate. With a closed shape, it is necessary to realize that if we add together all the rotational angles (δ), they form a circle and therefore the angles together measure 360°.

The elements of contrariety that are present here concern the arrangement of the angles. The function and salience of the angles (right angles versus non right angles) need to be focused on and transformed into their contraries: the δ angles assume a central role while the right angles play a secondary role and somehow go in the background in the process needed in order to find the solution.

The fifth problem was the matches problem (Katona, 1972). Here the task is to transform the five squares of the initial configuration into four squares of the same size, moving only three matches.

As we can see in Figure 9.5, the solution is to move the three matches indicated by A, B, C from the bottom of the configuration to the top, to create a new square. In addition to the top-bottom contrariety, the transformation consists of a transformation which means that a closed shape in the initial configuration becomes a part of background (i.e. an empty space) in the new configuration and vice versa (i.e. a part of space which was empty background in the initial configuration becomes a space which is delimited and has an inner surface in the final configuration).

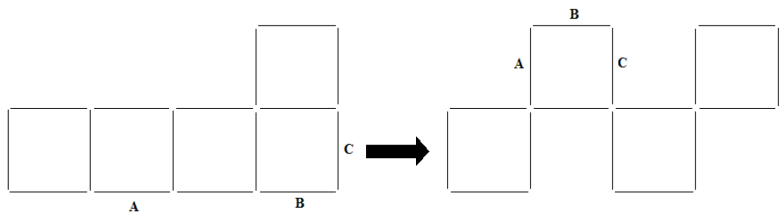

Figure 9.5 The matches problem (problem 5, Table 9.1): initial configuration and its solution.

The sixth problem considered was the square problem (Kanizsa, 1973). It consists of creating a square starting from six shapes: four identical isosceles triangles and two right angled trapeziums of the same height but with unequal bases (see Figure 9.6). The task is to transform many separate shapes into a single shape (and this is the first contrariety). Moreover, the solution means changing the original disposition of the shapes: the oblique sides of the triangles move to form the vertical and horizontal sides of the square in the new configuration. In addition, the 4 elements positioned identically in the initial configuration are re-positioned in a completely non-identical way in the new configuration: at the top of the new figure, the two isosceles triangles slightly touch each other in a vertex, while at the bottom the two isosceles triangles are adjacent, with an entire side in common.

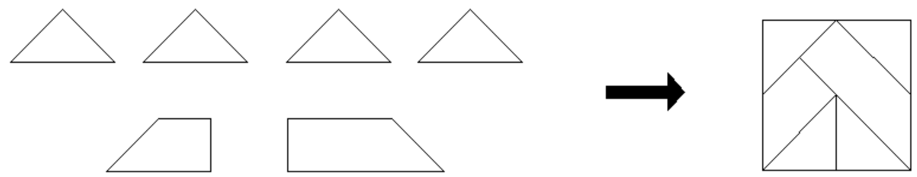

Figure 9.6 The square problem (problem 6, Table 9.1): initial configuration and its solution.

Problem number seven, the parallelogram-square problem, is again by Kanizsa (1973). This problem involves calculating the area of a given configuration, made up of two figures - a parallelogram (APCQ) and a square (ABCD) (see Figure 9.7). In order to reach the solution, it is necessary to "break" the lines forming the parallelogram and those forming the square to form two right angled triangles which partially overlap, one pointing up (PDC with the vertex P) the other pointing down (ABQ with the vertex Q). It is then possible to multiply the base of the square (CD) by the side PD, and thus find the total area of the two figures.

A critical aspect of the of the transformation is therefore the *part-whole* contrariety: the parallelogram which was a whole shape in the initial configuration becomes part of the triangles in the final configuration. The solution also involves transforming two overlapping shapes (one in front and the other behind) into two juxtaposed co-planar shapes.

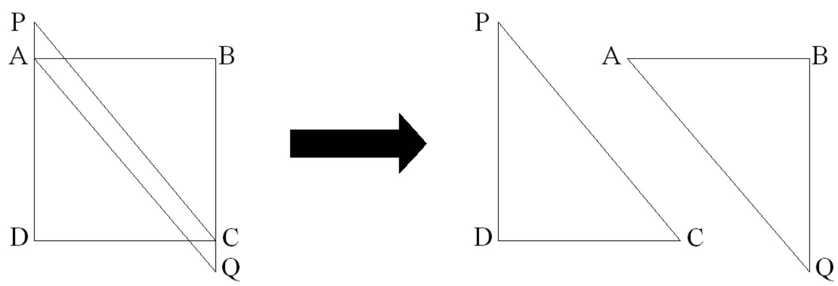

Figure 9.7 The parallelogram-square problem (problem 7, Table 9.1): initial configuration and its solution.

The task in the “nine points” problem (Maier, 1931) is to draw a line connecting nine dots arranged in 3 rows and 3 columns (see Figure 9.8, left hand diagram) without detaching the pencil from the sheet and without passing twice over the same dot. The idea is not to be “trapped” into believing that the 9 points perceptually create a closed figure (namely a square). The solution is reached by using not only the space “inside” the square, but also the surrounding area (see Figure 9.8, diagram on the right). The cognitive transformation of a space perceived as limited into an unbounded space is the key here.

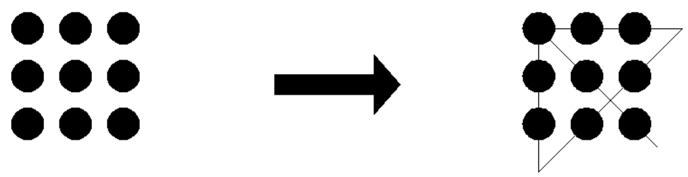

Figure 9.8 The nine-points problem (problem 8, Table 9.1): initial configuration and its solution

For the ninth problem, we looked at another one by Maier (1931): the two-cord problem. Two cords hanging from a ceiling have to be tied together. However, they cannot be held in the hands at the same time. Various tools are provided for the task, among them a pair of pliers. The solution consists of using the pliers (P in the Figure 9.9) to join the two cords (C1 and C2) at the bottom, using the pliers as a pendulum (see Figure 9.9, the diagram on the right).

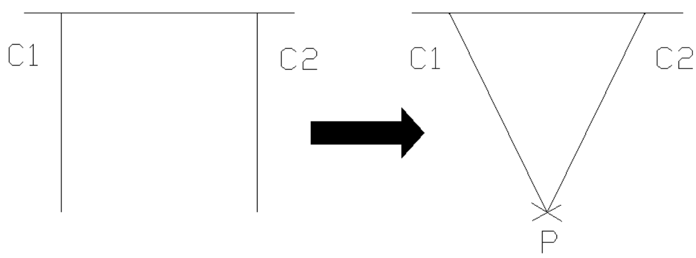

Figure 9.9 The two-cord problem (problem 9, Table 9.1): initial configuration and its solution. This is a schematic representation: the horizontal line represents the ceiling and the two vertical lines are the two cords hanging down. The letters C1 and C2 refer to the two cords, while the letter P represents a pair of pliers.

The solution requires joining separate elements. In order to do this, it is necessary to ignore the normal function of the pliers (i.e. cutting and bending) and use them as a pendulum. Contrariety is thus involved in this problem in that two separate elements are unified. This is visible not only when comparing the bottom of the cords before and after the solution, but also when comparing the top and bottom after the solution. Furthermore, another key element is that the pliers are rigid and heavy (which is why they swing like a pendulum), while the cords are flexible and light.

The final problem is the duck problem (Harrower, 1932) which is as follows: "Two ducks in front of two ducks, two ducks behind two ducks, and two ducks in the middle swim under a bridge. How many ducks are there?". The creative solution is not "6 ducks", but "4 ducks".

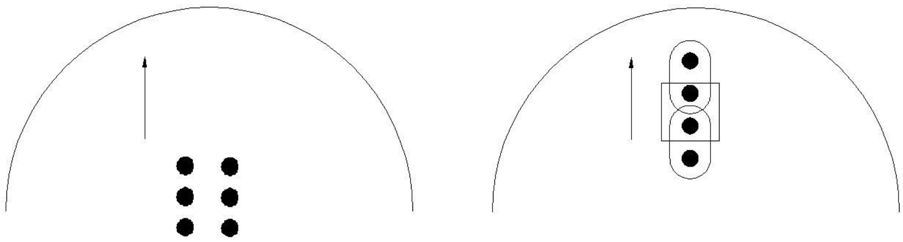

Figure 9.10 The duck problem (problem 10, Table 9.1): obvious, non-creative solution (diagram to the left) and creative solution (diagram to the right).

The immediate solution that comes to mind is that the 3 pairs of ducks are positioned as in Figure 9.10 (diagram on the left). This is triggered by that fact that we tend to imagine "a pair" as being formed of two elements placed side by side. In order to reach the creative solution, one needs to change the disposition of the two elements in the pair from horizontal to vertical (Figure 9.10, diagram on the right). This spatial transformation from horizontal to vertical once more represents an example of contrariety.

In conclusion, this analysis of classic problems (and their respective solutions) seems to support the hypothesis that the solution to a problem usually involves re-structuring some elements of the initial configuration into opposite elements.

In order to further verify this hypothesis, we carried out two studies. In both studies we aimed to establish whether contrariety facilitates the solution process. In Study 1, the sample of participants consisted of thirty adults and in Study 2 of twenty-four children (all about nine years old). The aim was to assess the plausibility of an empirical study of the hypothesis. Results need to be considered qualitatively and are discussed accordingly.

9.4 Study 1

The aim of the study was to verify whether the search for contrary properties in the structure of a problem facilitates the process of solution. This was measured in various ways: the reduction in time needed; the number of problems successfully resolved; the type and number of solutions thought up and tested and the perception of how easy or satisfying the task was.

Method

Procedure. Participants took part in the study in inter-observational groups (of three participants each). Two conditions were considered: an experimental condition and a control condition. In both conditions participants had to read and solve a given number of problems but in the experimental condition participants were asked to identify any contrary properties present in the structure of the problem before embarking on the solution process. There was no time limit, either in the initial phase of the groups in the experimental condition or in the phase devoted to the solution of the problems. Participants were free to use as much time as they wanted or needed. Each session was recorded by video camera and took place in the presence of the experimenter. The study took place in the psychology laboratory at the University of Verona.

Problems. Three problems were presented to all groups: the parallelogram problem (Wertheimer, 1965), the nine points problem (Maier, 1931) and the duck problem (Harrower, 1932).

Participants. Thirty undergraduate students at the University of Verona (there were five groups of three people in the experimental condition and five groups of three people in the control condition).

Results

We analysed the data obtained considering five variables: time, contraries, the satisfaction of discovery, the solution process and the typology of the solutions proposed.

Time needed. We used the video recordings to divide the experimental session into intervals corresponding to the various phases of the experiment: the time needed to read the instructions before the presentation of the three problem (t0); the time to read the text of each problem (t1); the time necessary for the comprehension of the problem (which extended from the end of the reading of the problem to the beginning of the dialogue between the members of the group) (t2); the time necessary to find contrary properties in the structure of the problem ($t3_1$) – this only applied to the experimental condition and the time spent finding a solution ($t3_2$). We predicted that if the search for contraries in the initial phase ($t3_1$) facilitates the search for a solution, the time spent by participants in the experimental condition would be shorter than for the control groups. Figure 9.11 presents a comparison of the mean times used by the groups to find a solution to all three problems ($t3_2$), in the experimental and in the control condition. Data confirm the prediction.

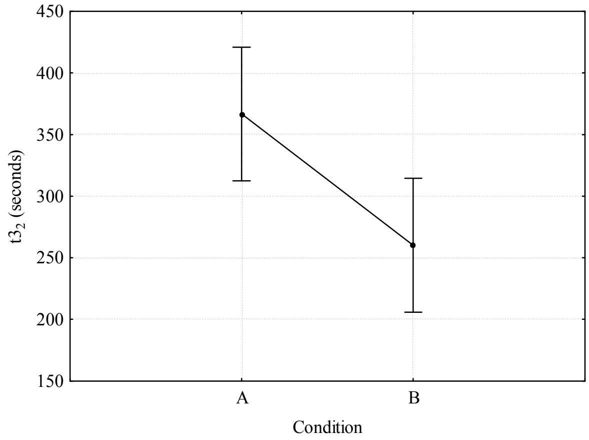

Figure 9.11 Average time (in seconds) necessary in the control condition (A) and in the experimental condition (B) to reach the solution of the three problems proposed.

Number and type of contraries used. We examined the number and type of contraries identified by the groups in the control and experimental conditions during the search for a solution ($t3_2$). As shown in Figure 9.12, the average number of contraries was higher for the groups in the experimental condition, in all three problems, both when spatial versus non-spatial contraries were considered and when contraries which were potentially relevant to the solution of the problem were considered as compared to those which were not.

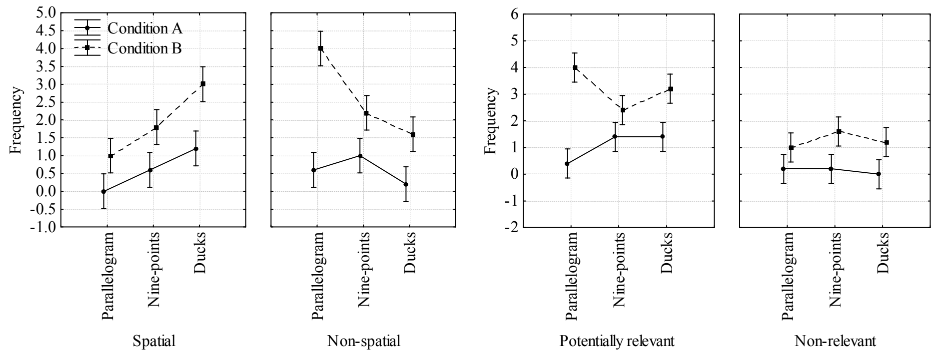

Figure 9.12 Mean number of contraries used by experimental (B) and control (A) groups when searching for a solution to the problem.

A possible explanation for this is that participants in the experimental group activated a strategy of systematic transformation of the elements of the problem into their contraries in order to discover whether this would lead to the solution. This would mean that they carried out the same process for some aspects (spatial or non-spatial) that were not relevant to the solution.

Satisfaction of discovery. We considered the emotions shown by the people in the groups during the experiment by analysing the video recordings. We focused on the facial expressions of participants when searching for solutions (Ekman & Oster, 1979) and categorized them according to positive and negative emotions, as suggested by Oatley (1997).

As shown in Figure 9.13, there seem to be a slight tendency for the participants in the control group to manifest more negative emotions than participants in the experimental condition.

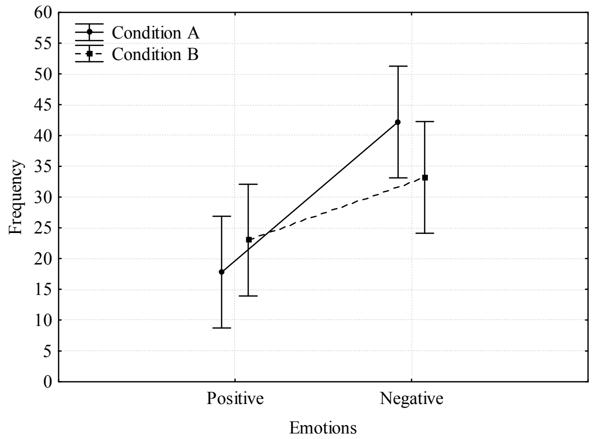

Figure 9.13 The frequency of positive and negative emotions felt by the groups (experimental, B, and control, A) during the course of the experiment.

According to Oatley (1997), this can be explained by the fact that a positive emotion is activated when a goal is reached or when there is high engagement in the execution of the task, while a negative emotion is activated when there is an insurmountable difficulty or when engagement in the task is low. Participants of the experimental groups in effect turned out to be more engaged in the task than the control groups.

The solution process. We analyzed the process by which the groups reached the solutions by considering the number of verbal communications exchanged by the members of the groups, with reference to which phase of the solution process was underway the analysis of the problem, the explanation of different stages (that is the explanation of the procedure used in order to arrive to the proposed solution), the discussion regarding possible solutions, the number of attempts before arriving at the correct solution, various solutions. Looking at the total percentages by row, it seems that in general the structure of the process did not differ much in the two conditions. There seemed only to be a tendency of the groups in the experimental condition to pay more attention to the initial analysis of the structure of the problem and to propose more solutions, in addition to a slight tendency of the groups in the control condition to verbally repeat the steps involved in the reasoning process (Table 9.2).

Table 9.2 Number of verbal communications exchanged by the members of the groups with reference to the phase of the solution process for the three problems.

Stages of the solution process	Condition	Total (for the three problems)	Total in %
Analysis of problem	Control	56	47.06%
	Experimental	63	52.94%
Explanation of stages	Control	31	54.39%
	Experimental	26	45.61%
Discussion	Control	228	50.33%
	Experimental	225	49.67%
Number of attempts	Control	83	51.55%
	Experimental	78	48.45%
Proposal of solutions	Control	28	47.46%
	Experimental	31	52.54%

Types of solution. We examined the types of solution considering first of all the number of inter-observational groups that reached the correct solution to all three problems: this happened more frequently in the experimental condition (4 groups out of 5), than in the control condition, where only 1 group (out of 5) successfully resolved all three problems. Therefore, there seems to be a clear indication that the initial phase involving the identification of contrary properties inherent to the problem is associated with a higher success rate.

We classified each solution proposed first of all distinguishing between what we referred to as "reasoned solutions" (i.e. solutions resulting from a new reasoning process) and "scholastic solutions" (i.e. solutions found by means of the mechanical application of previously learned knowledge). We also made a distinction between conventional and alternative solutions. For example, in the duck problem, a correct but conventional solution is to say that there are 6 ducks (because of the conventional horizontal disposition of a pair of elements); we classified as alternative more creative solutions which for instance involved imagining the ducks positioned in vertical pairs, or with a rhomboidal disposition. Similarly, for the parallelogram problem, the (correct) solution involving transforming the parallelogram into a rectangle was considered to be conventional, while alternative solutions put forward by participants included, for example, Euclidean and Pythagorean theorems applied to the problem in order to explain how to calculate the formula. The distinction between "congruent" and "non-congruent" solutions (i.e. compatible with the solution of the problem or not) was defined on the basis of whether any of the information present in the formulation of the problem was violated. For instance, in the duck problem, a solution was judged to be non-congruent when the solution no longer included the information that the ducks were in pairs.

Table 9.3 Number of reasoned, scholastic, alternative, conventional, congruent and non-congruent solutions, for each of the three problems, in the experimental and control conditions.

Problem	Condition	Reasoned	Scholastic	Alternative	Conventional	Congruent	Non-congruent
Parallelogram	Control	2	3	1	4	5	0
	Experimental	3	2	3	2	5	0
Nine points	Control	1	0	1	0	1	0
	Experimental	4	0	4	0	4	0
Ducks	Control	8	0	1	7	7	1
	Experimental	11	0	6	5	6	5
Total	Control	11	3	3	11	13	1
Total	Experimental	18	2	13	7	15	5

Looking at the totals in Table 9.3, some differences between the two conditions emerge. The number of reasoned and alternative solutions was higher in the experimental condition than in the control condition, whereas the number of conventional solutions was higher for control groups. There also seemed to be a tendency to produce non-congruent solutions more often in the experimental condition than in the control condition, and this may suggest that in the process of "diverging" from the initial structure of the problem when looking for a solution, participants sometimes went too far and lost part of the information that in the process of transforming the initial aspects configuration into their contraries needed instead to be preserved.

9.5 Study 2

In the previous study, we found that requesting participants to search for contrary properties in the structure of the problem yielded improvements in the execution of the task in various ways :reduction in the time required to reach the solution, creation of a less negative emotional atmosphere, more attention to the analysis of the structure of the problem and more "correct" and "creative" (alternative and reasoned) solutions. The second study aimed to verify whether similar results would be found if nine year old children were considered instead of adults.

Method
Procedure. The procedure was similar to that used in Study 1. Participants took part in the study in inter-observational groups. The same two experimental conditions were considered. In this case, since minors were involved, we did not used video recordings and the experimenter compiled observational reports on the variables to be considered during the study. Each session occurred in the presence of the experimenter. The aim

was to create a playful atmosphere. The instructions and explanations were given orally. Some materials were also provided: sixteen card strips for the Katona's matches problem and 6 pieces of card cut into shapes for Kanizsa's problem.
Problems. Three problems were proposed out of those in Table 9.1: Katona's matches problem (1972), Kanizsa's square problem (1973) and the Harrower's duck problem (1932).
Participants. Twenty-four nine year old primary school children. They were divided into eight groups: four in the control condition and four in the experimental condition.

Results

We analysed the data obtained considering the same five variables as in the Study 1: time, contraries, the satisfaction of discovery, the solution process and typology of solutions.
Time. As in Study 1, the groups in the experimental condition were quicker at reaching the solution than the control groups (see Figure 9.14). The time interval considered was that between the start of the search for a solution and the end of the process – referred to in Study 1 as $t3_2$.

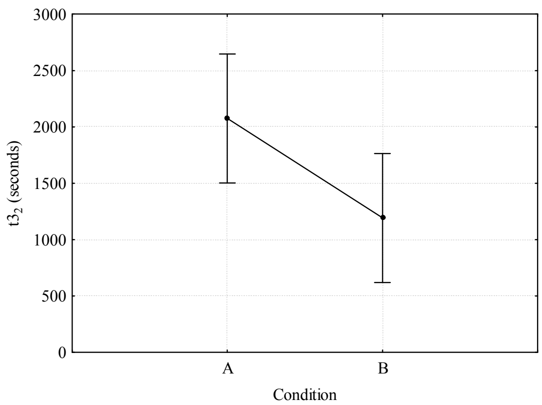

Figure 9.14 Average time required by the groups (experimental, B, and control, A) to reach the solution to the three problems.

Number and type of contraries used. A comparison between the total number of contraries used in the search for a solution confirmed what was found in the previous study. In this case too the contraries used were divided in spatial contraries and non-spatial contraries (since space was an important feature of the problems) and we also distinguished between contraries which were relevant and those which were not-relevant to the solution. As shown in Figure 9.15, participants in the experimental condition used a greater number of contraries.

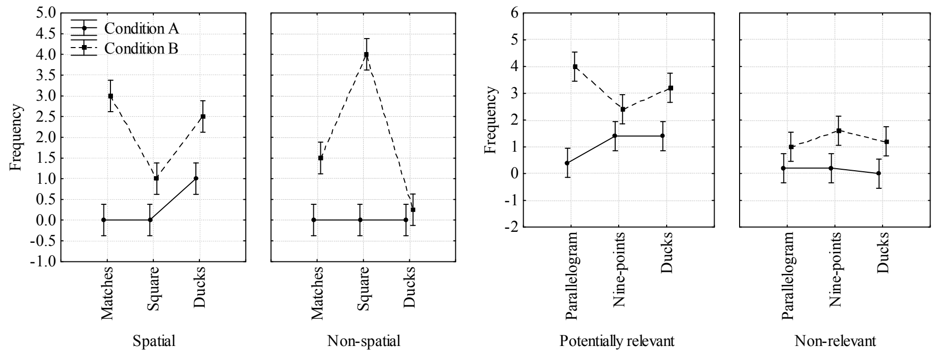

Figure 9.15 Mean number of contraries used by experimental (B) and Control (A) groups when searching for a solution to the problem.

Satisfaction of discovery. A comparison between the frequency of positive or negative emotions manifested by participants' facial expressions demonstrated even more clearly than in the previous study that there were emotional differences between the two conditions (Figure 9.16). Participants in the experimental condition manifested a higher frequency of positive emotions and also a higher frequency of negative emotions.

This suggests that there was a higher emotional involvement in the task than in the control condition. In general, observing the trend of the two types of emotions, in the experimental group there was a positive rather than negative atmosphere and participants were not disappointed by failures; in the control group the tendency was in the opposite direction.

Solution process. With respect to the various phases leading to the solution of the problem (see Table 9.4), as in Study 1, the behaviour of the groups in the two conditions was generally very similar. In particular, no differences emerged with respect to the category "analysis of the problem" (in Study 1, in the experimental condition, participants paid more attention to this aspect).

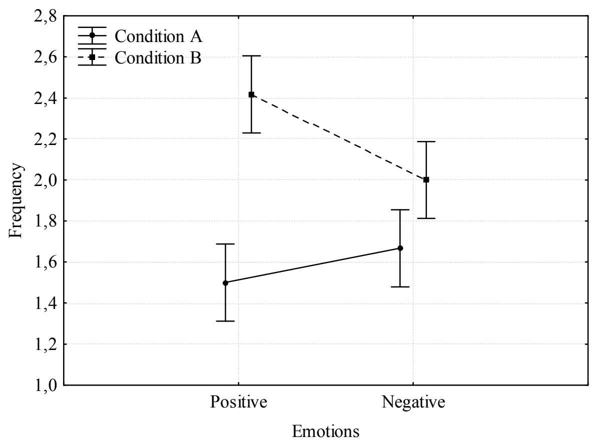

Figure 9.16 Frequency of positive and negative emotions (as manifested by facial expressions) in the two conditions.

A difference seem to emerge only with respect to the number of solutions proposed, which was higher in the experimental condition (as in Study 1), and the discussion (richer in the experimental condition).

Table 9.4 Number of verbal communications exchanged by the members of the groups referring to various aspects of the solution process for all three problems.

Stages of the solution process	Condition	Total (for the three problems)	Total in %
Analysis of problem	Control	4	50%
	Experimental	4	50%
Explanation of stages	Control	5	41.67%
	Experimental	7	58.33%
Discussion	Control	6	35.29%
	Experimental	11	64.71
Number of attempts	Control	36	47.39%
	Experimental	40	52.63%
Proposal of solutions	Control	16	43.24%
	Experimental	21	56.76%

Types of solutions. We examined first of all the number of groups which managed to come up with the correct solution for all three problems. In the experimental condition, all groups succeeded in all three problems, and in the control condition 3 groups were successful out of 4. The advantage of the groups in the experimental condition is not as evident here as it was in Study 1 (this might also suggest that the problems were easier to solve for older participants).

We investigated whether there were differences regarding the type of solutions found (Table 9.5).The categories of solutions considered conventional versus alternative solutions, and congruent versus non-congruent (i.e. solutions that violate or do not violate the information present in the formulation of the problem). As the totals reveal, no differences emerged between the two conditions for any of the variables considered.

Table 9.5 The table refers to the types of solutions proposed for each problem. For the category , see text.

Problem	Condition	Conventional solutions	Alternative solutions	Congruent solutions	Non-congruent solutions
Matches	Control	2	2	4	0
	Experimental	1	3	4	0
Square problem	Control	0	3	3	0
	Experimental	0	4	3	1
Ducks	Control	4	1	4	1
	Experimental	5	0	5	0
Total	Control	6	6	11	1
	Experimental	6	7	12	1

To summarise, in this study, the initial exploration of the contrary properties present in the structure of the problem led to an advantage in problem solving with respect to three out of the 5 variables considered. In the experimental condition, the amount of time needed to find the solution was reduced; the number of contraries elicited was higher (and this testifies that they were somehow applying the process as stimulated in the initial phase) and the positive emotional reactions were more frequent. No major differences emerged within most of the phases of the process, except for the fact that there was a tendency to find more alternative solutions in the experimental condition, and that there was a slight difference in the number of groups that reached the solution to all three problems. The absence of a clear advantage in the experimental condition with respect to the other indexes in Study 2 may be due to the fact that the problems considered were relatively easy for the children, whereas the problems considered in Study 1 with adults were more difficult. The advantage observed in the experimental condition had in fact more to do with the general strategy used (i.e. they more often referred to contraries when searching for a solution) and with the speed of the process, than with finding versus not finding a solution.

9.6 Conclusions

Our study of the type of transformations implied in the solution processes for 10 classic cognitive problems and the results of the two studies conducted both support the hypothesis that contrariety in effect plays a role in the process of problem solving.

An analysis of the structure of the initial problem and of the transformation required to reach a solution revealed that the process invariably involves changing some precise and usually salient characteristics of the initial configuration into their opposites. The studies confirmed that if participants are encouraged to analyze the structure of the problem in terms of the properties which characterize the initial configuration and their opposites, they tend to use the same reasoning during the solution process (this is true for both Study 1 and Study 2). This in turn is associated with a greater success rate (Study 1) and with speeding up the process and increasing the number of non–conventional but alternative, more creative solutions (both studies). With adult participants, there was evidence that, in terms of the steps involved in the process, participants improved in particular the initial analysis of the structure of the problem and their proposals for various solutions. An indication of a more positive emotional engagement in the tasks emerged from both studies.

There results are of course not definitive. However, it seems to us that they confirm, on one side, that people recognize the properties of a given event (in this case a problem) in terms of properties that can be transformed into their opposites. We also suggest that it is worth looking more deeply into how this can affect the facility with which people produce creative, non-conventional solutions, thus opening a new chapter which may contribute to the understanding of the cognitive conditions supporting problem solving and the cognitive bases of creative processes in general.

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