5

Contrariety in plane mirror reflections

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5.1 Old and new questions

The idea that contrariety is one of the components of mirror images is, in one sense or another, the starting point of all the literature which has evolved in the field of psychology under the umbrella of the "mirror question": why do mirrors reverse left and right but not up and down?. This has been in the main stream of discussion concerning mirror reflections in Cognitive Sciences from the nineteen seventies to the very beginning of the present century (Bennet, 1970; Corballis & Beale, 1976; Ittelson, 1993; Ittelson, Mowafy & Magid, 1991; Gardner, 1964; Haig, 1993; Tabata & Okuda, 2000; Corballis, 2000; Morris, 1993; Navon, 1987, 2001; Takano, 1998; Gregory, 1987, 1996). From that time on, naïve optics emerged as a new chapter in naïve physics, and researchers started to direct their attention towards a new sample of questions concerning what people know about mirrors and the behavior of reflections:

1. is the optical law of reflection (i.e. that reflected rays are at the same angle as incident rays) generally known by naïve adult subjects? – see Croucher, Bertamini & Hecht, 2002);
2. when approaching a mirror walking parallel to it, at what point would people expect to see themselves appear in the mirror? Would they expect to appear at the nearest or farthest edge of the mirror? (See Bertamini, Hecht & Spooner, 2003; Croucher, et al. 2002; Hecht, Bertamini & Gamer, 2005; Lawson & Bertamini, 2006; Jones & Bertamini, submitted);

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3. do people know that the size of their own face reflected on the surface of the mirror is half the width and height of its real size? (See Bertamini & Parks, 2005; Lawson et al., 2006);
4. do people generally believe that their reflection appears smaller as they move away from the mirror? And what about the reflections of other people? (See Bertamini & Parks, 2005); and finally,
5. does the amount of background visible in a mirror change depending on the observer's vantage point? And how does the relationship between an object and its reflection affect the perception of distance and size? (See Jones & Bertamini, 2007; Jones & Bertamini, submitted).

References to contrariety in this list of questions seem to disappear together with interest in the mirror question. It is true that the debate on left-right-but-not-up-down inversion developed more as a theoretical dispute on a problem that has often been considered artificial, rather than a real question to be answered by means of experimentation. This charge of artificiality was based on two different arguments. The first is that the question hides the linguistic confusion between different frames of reference: when the *left* and *right reversal* is described, we are assuming an egocentric frame of reference, while when the *up* and *down* non-reversal is described, we are assuming an environmental or allocentric frame of reference. The conclusion, for supporters of this point of view, is that correcting the description would make the pseudo-problem disappear (Block, 1974; Gardner, 1964; Ittelson, 1993; Ittelson et al., 1991; Morris, 1993). The second argument states that there is no reversal since a point-by-point transformation or a transformation into the fourth dimension make the geometrical correspondence between virtual and real objects clear (Gregory, 1996; Tabata & Okuda, 2000).

We have already commented on both these criticisms. With respect to the latter argument, we have noted that saying that a given object can coincide with its reflection by appropriate geometric operations does not offer a "simple and definitive solution to the mirror reversal problem" (Tabata & Okuda, 2000, p. 170) at all, at least not for the psychologist. As Takano (1998, p. 27) observed "according to this line of argument (…) one could maintain that the Müller-Lyer illusion, for example, is not worth investigation because the two compared lines are identical in length from a geometrical point of view." Arguments involving physics represent a modern case of 'stimulus error' (Boring, 1921; Savardi & Bianchi, 1999; Jameson, Bimler, Dedrick & Roberson, 2007), i.e. a description of the physical stimulus in place of the perceptual phenomenon. With respect to the former criticism, we have argued that the use of two different frames of reference (egocentric and allocentric) in the analysis of the geometry of mirror reflections, is not a linguistic error but the genuine core of the question, as we will see later in this chapter (see also Savardi & Bianchi, 2005; Bianchi & Savardi, 2008b).

So now the question becomes: is left-right contrariety part of the *phenomena* concerning mirrors that a researcher interested in human perception and cognition of reflections can include in the list of questions to be empirically answered? And is it *the only case* of contrariety which is directly experienced by naïve subjects looking at their image in a mirror?

5.2 Egocentric left-right reversal is a perceptual datum, but not the only contrariety

If one asks people to describe what they see when looking at themselves or at another person in a plane mirror (an "everyday" mirror), what would they say? Would they have reasons based on perception to say that the reflection is opposite to themselves?

Let us start wondering this last question with respect to the left-right reversal. Would observers have reasons based on perception to say that the reflection is opposite in terms of left-right? Of course they would. In the top left diagram of Figure 5.1, the fact that the person seen from back view has the *right* arm extended while, in the reflection, it is the *left* arm is something that one can *see*. In the same way, in the other two diagrams in the top row, we can *see* that the person's *left* arm is extended while, in the reflection, it is the *right* arm. This is a true description of the scene, if one adopts the body of each individual (real or reflected) as a frame of reference.

But is this egocentric contrariety the only contrariety that is noticed when comparing real and reflected bodies? A series of experiments conducted with adult participants observing their own and another person's reflections in a "mirror room" with plane mirrors set on the floor, on the ceiling, in front and beside the observers demonstrated that people do not notice this egocentric contrariety (Savardi & Bianchi, 2005; Bianchi & Savardi, 2008b). Rather, when asked to describe the relationship perceived between their body and its reflection, they more frequently noticed and reported other contrary aspects. These all concerned the opposite orientation of the body or of parts of it with respect to the environmental (or allocentric) frame of reference.

Before considering participants' responses, let us take a look at the arrows in Figure 5.1 which describe, in terms of vectors, the spatial orientations of the real and reflected body as defined within an allocentric frame of reference. The figures in the first row – and their simplified representation in terms of vectors in the second row – make it clear that the body axes that are parallel to the mirror point in the same direction in both real and reflected worlds. Conversely, the body axis that is orthogonal to the mirror has a contrary direction on the other "side" of the mirror.

This schema also holds for dynamic behavior. Consider the vectors in the second row of Figure 5.1. Take, in turn, one of the vectors on the side of the real world as a representation of an object in motion. Let's say, for example that the object is moving along y in the diagram on the left, along z in the central diagram and along x in the diagram on the right. You will quickly agree that the reflections would move according to the corresponding reflected vectors in the three diagrams.

Consider now a further case, i.e. that of an object which is moving (or is oriented) at an angle of incidence that is different from the angles considered thus far (i.e. parallel or orthogonal to the mirror surface). In the diagrams in the third row of Figure 5.1 we have represented the case of a movement or orientation at an angle of incidence of 30° (the solid lines); we have considered inclinations relative to two and not three axes for simplicity. In this case too the relationship between real and reflected movements/orientations complies with the rules seen before which apply to orthogonal and parallel vectors. In this case the two are combined as component vectors of the final movement, that in vector algebra is called the "resultant vector".

Therefore, whatever the angle of incidence, the spatial orientation of reflections with respect to the real body manifests identity and contrariety, according to the rules described thus far in terms of x, y, and z axes, and depending on the reciprocal position of the real body/object with respect to the mirror. One might consider the condition represented in the third row of Figure 5.1 as the general case and deal with movements (or orientations) parallel to the mirror and orthogonal to the mirror as two special cases, where two out of the three vectors are null.

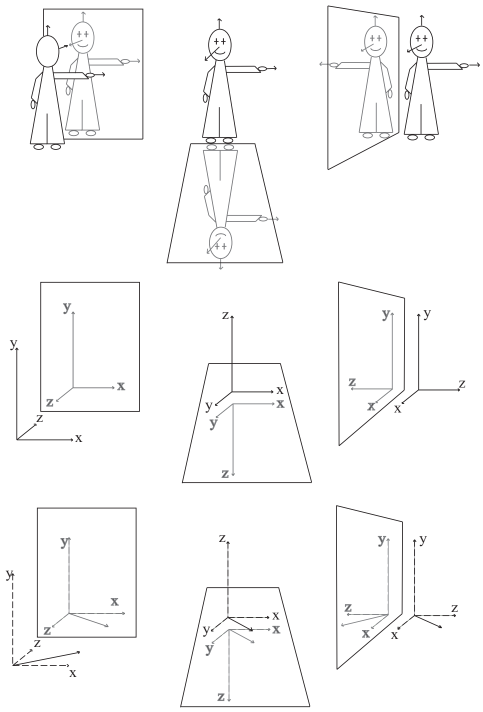

Figure 5.1 Representation of the relationships between the spatial orientation of real and virtual bodies (defined by the three axes of the body: gravitational, coronal and sagittal), in terms of vectors defined in a cartesian space. By convention, we call x and y the two axes forming the plane parallel to the mirror surface, and z the third axis, orthogonal to it. In the second row the same relationships shown in the first row are represented in terms of mere vectors. In the third row, the case of non-orthogonal and non-parallel movements or orientations is considered (the broken lines show that the same orthogonal and parallel vectors of the second row here function as the component vectors of the solid line – the resultant vector).

This analysis of the "geometry of mirrors" in terms of identically oriented and contrarily oriented vectors is purely descriptive and does not involve theories or beliefs about the physics or geometry of reflections. It simply complies with what one might see when comparing orientations, gestures or movements in front of a mirror with their reflected counterpart. If these perceptual relationships are also noticed and experienced in this way by naïve observers, then we should expect that their descriptions of the relationship perceived when looking at their mirror image is mostly in terms of identity or contrariety, according to the vector patterns described in Figure 5.1. If this is the case, we have valid support for an analysis of the perceptual structure of mirror reflections in terms of identity and contrariety.

5.3 What people see when they look at their reflections

In three experiments we analyzed adults' direct experience of their reflections (see Savardi & Bianchi, 2005; Bianchi & Savardi, 2008b). The purpose of the experiments was to test whether contrariety, together with identity, is a perceptually salient datum in people's experience of their own or other people's reflected images. It is an undeniable perceptual fact that, in classic reflections in single plane mirrors, the reflected body moves the left arm when the real body moves the right arm and *vice versa*. However, it is a similarly undeniable datum that, when people look at themselves in a mirror, the reflection has a contrary orientation, i.e. the real person is facing north whereas the reflection is facing south. This last contrariety, which emerges when the allocentric frame of reference is considered, has not been paid attention to at all by researchers engaged in the old debate on the mirror question. However this does not automatically mean that naïve subjects ignore this aspect.

In effect, various frames of reference are involved in mirror image perception, in the same way as various frames of reference are involved when the relationship between two independent bodies is considered. At least two frames of reference need to be considered: egocentric and allocentric (see also Savardi & Bianchi, chapter 3 in this volume, § 3.3 and 3.4). The *egocentric* frame of reference is founded on the individual body schema and is established by means of "in front-behind", "above-below" and "left-right" coordinates. Using this frame of reference I can determine which is my "real" left (or right) arm and which is the reflection's left or right arm (and therefore also recognize that they are inverted). The *allocentric* frame of reference is determined by the environment. According to this second frame of reference, the two bodies in the top left diagram of Figure 5.1 have an opposite sagittal orientation (but an identical gravitational and coronal orientation), whereas the two bodies in the top center diagram have an identical sagittal and coronal orientation but a contrary gravitational orientation and the two bodies in the top right diagram have an opposite coronal orientation (but an identical sagittal and gravitational orientation).

The importance of the allocentric frame of reference in the relationship perceived between human bodies clearly emerged from previous research in which adult participants and children aged 7-9 were asked to produce a contrary or an identical gesture with respect to a target gesture (see Bianchi & Savardi, 2008a, pp. 101-112). In the great majority of cases, participants founded their responses on the allocentric frame of reference. For instance, as shown in Figure 2, when oriented face to face with the target body, they did the "contrary" of the target gesture by moving the allocentrically opposite arm in the allocentrically opposite direction. In terms of the egocentric frame of reference this corresponds to doing exactly the same as the target gesture (left arm to the left). In the same way they usually "did the same" by moving the allocentrically identical arm in the allocentrically identical direction. Again, in terms of an egocentric frame of reference it would be surprising if participants did this since it would mean that they were moving the opposite arm (right instead of left) in the opposite direction (to the right instead of to the left). They evidently did not "code" the gesture in terms of egocentric coordinates, but in terms of allocentric space. Both in imitative tasks and in tasks asking them to do the contrary, participants very rarely identified a target gesture such us that presented in Figure 5.2 in terms of "right arm stretched out to the right". They usually identified it as "arm on that side [say, west] stretched toward that side" and reacted accordingly.

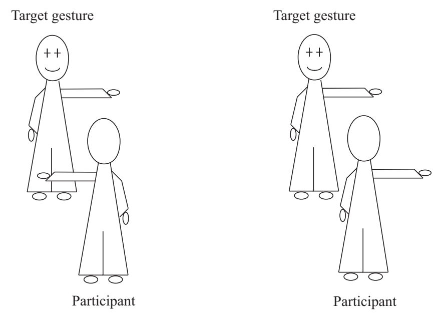

Figure 5.2 Examples of the response usually given by adult and child participants when asked to "do the opposite" of the target (figure on the left) or "do the same" as the target (figure on the right).

Now let's go back to mirrors. There are no reasons, *a priori*, to expect that the perception of the spatial relationship between a reflected body and a real body does not comply with the same perceptual rules which apply to the relationship between two real bodies.

Given a single plane mirror, the differences between real and reflected bodies fall into three categories. These involve placement, orientation and structure (Savardi & Bianchi, 2005; Bianchi & Savardi, 2008b).

In terms of placement, the observer-reflection relationship is always characterized by the reflected image being localized over/under, to the right of/to the left of, or in front of/behind the observer.

In terms of allocentric orientation, given the structure of the human body with its two main axes of orientation (one structured by the line of sight, the other structured by gravitational orientation), differences in orientation, when present, are contrary orientations. Thus, when the observer faces north, the reflection either faces north too (Figure 5.1, diagrams top center and right) or, alternatively, faces the contrary direction, i.e. south (Figure 5.1, top left), depending on the position of the mirror. With respect to gravitational orientation, when the observer is standing upright, the reflection is either upright (Figure 5.1, diagrams top left and right) or upside down (Figure 5.1, top center diagram).

In terms of egocentric body structure, the reflection is opposite left-right.

Analytically, the description of the spatial characteristics of reflections with respect to real bodies can be accounted for in terms of these three variables. But what if we consider the actual perception of observers when they look at their reflections? They obviously recognize themselves, but we might ask if they have a complete experience of sameness or notice some differences (or rather contrarieties). In particular, we might ask whether they notice the egocentric left-right reversal of the mirror image or notice allocentric contrarieties in the orientation of the reflection.

We addressed these questions by asking observers to inspect various reflections and to answer a series of questions (see Bianchi, Savardi & De Lotto, 2003; Bianchi & Savardi, 2008b). A mirror room was set up for the experiments. It consisted of two 2.5m x 2m plane mirrors, placed vertically and orthogonally to form the two adjacent walls of the mirror room and two 2m x 2m mirrors, lying horizontally to form the ceiling and the floor. The apparatus was built to allow participants to stand on the mirror on the floor.

Various observer-reflection configurations were observed and described by participants. These configurations varied depending on:

1. the position of the mirror in relation to the observer: we studied reflections generated by mirrors set vertically on the wall (frontal reflections) versus reflections generated by mirrors lying horizontally on the floor;
2. the absence or presence of cues emphasizing left-right lateralization (such as an arm stretched out);
3. the egocentric lateralization of the reflections: we used standard reflections (which are characterized by contrary left-right lateralization with respect to the real body) versus reflections generated by two adjacent mirrors positioned at right angles (which are characterized by identical left-right lateralization);
4. the type of gesture made by observers in front of the mirror.

The results unequivocally showed that recognition of identity and recognition of contrariety are both key elements in people's experience of their own or another body's reflection. In particular, with frontal reflections (i.e. reflections in a single plane mirror set vertically on the wall in front of the observer) they described the reflection as “identical” to themselves in about 90% of cases. Conversely, when looking at gravitational reflections (i.e. reflections in a single plane mirror lying horizontally on the floor), less than 5% of participants considered “identical” to be the best description and only 38% considered it adequate. Participants more frequently reported a general perception of contrariety: 50% of them judged this to be the best description of what they perceived, 88% considered it an adequate description.

Furthermore, in the frontal condition, when answering the question “how would you describe the orientation of the reflection with respect to your body?”, no less than 80% of participants recognized that the reflection had a contrary sagittal north-south orientation; a *smaller* number or responses (30%) revealed recognition of left-right contrariety. With gravitational reflections, more than 90% of participants described the orientation of the reflection as "contrary" to their own. In this case, they exclusively referred to the reversed allocentric up-down orientation and *never mentioned* the egocentric left-right reversal.

The importance of allocentric relationships was also confirmed when participants were asked to focus on the gestures in the reflections and to describe them with respect to the gestures made by the "real" person. The experiment showed that 73% of participants recognized that the reflected gestures failed to correspond to the real gestures. They were more frequently considered to be "contrary" (41%) rather than "similar" (27.7%) or "different" (7.2%). Again, an analysis of the responses in terms of egocentric versus allocentric frames of reference confirmed that, whatever the gesture and position of the mirror, "identical" was used to describe reflected gestures pointing in the same allocentric direction, while "contrary" was used to describe reflected gestures pointing in an opposite allocentric direction. When gestures were not static but moving, the evidence of contrariety became even greater (LR=3.187, df=1, p=0.05). Motion thus seems to emphasize the recognition of contrariety in the directional structure of gestures.

Of course all the results described thus far depend on the fact that the human body is characterized by precise asymmetries: the sagital (back-front) and gravitational (up-down) asymmetries are very evident and coronal asymmetry is much harder to perceive. If we replace the person in Figure 5.1 with a chromatically homogeneous sphere, the geometry described by the vectors x, y, z still holds in theory, but, perceptually, it becomes hard to recognize the directions of the vectors referring to identity and contrariety (described in the figure) which, in contrast, are very easy to see when an asymmetrical object is considered.

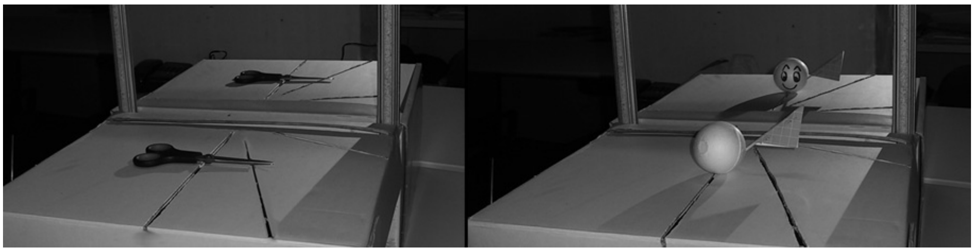

Figure 5.3 A pair of scissors (on the left) and a puppet (on the right) in front of a plane mirror. The reflection of the pair of scissor is perceived as having an identical orientation to the real object, while the reflection of the puppet as having an opposite orientation.

The geometry of the vectors in Figure 5.1 goes a long way towards accounting for the perception of mirror images and was confirmed also when objects were considered. When presented with the two scenes shown in Figure 5.3, where no human bodies were present, participants still behaved in agreement with the patterns of correspondence shown in Figure 5.1.

They were asked to look at an object in front of a mirror and at its reflection and to rate the degree to which they considered that three descriptions of the scene (in terms of contrariety, identity or rotation) was in line with their perceptual experience. The preference was for "identical" when the pair of scissors was under observation, and "contrary" with the puppet. The orientation along the x axis (in the case of the scissors) and the z axis (for the puppet) pops out due to the asymmetry of these two objects. "Identical" and "contrary" correspond with the relationship between the x and z vectors in Figure 5.1.

The pattern of correspondences represented in Figure 5.1 also explains the description given by participants when motion instead of static orientation was considered. The experimenter moved a ball towards and away from the mirror (by moving a stick under a box) along fissures made by cuts at 0°, 22.5°, 67.5°, 90° angles with respect to the mirror. As with the pair of scissors and the puppet, participants (25 undergraduate students) were asked to look at the object in motion and at its reflection and rate their agreement/disagreement with a series of sentences describing the relationship.

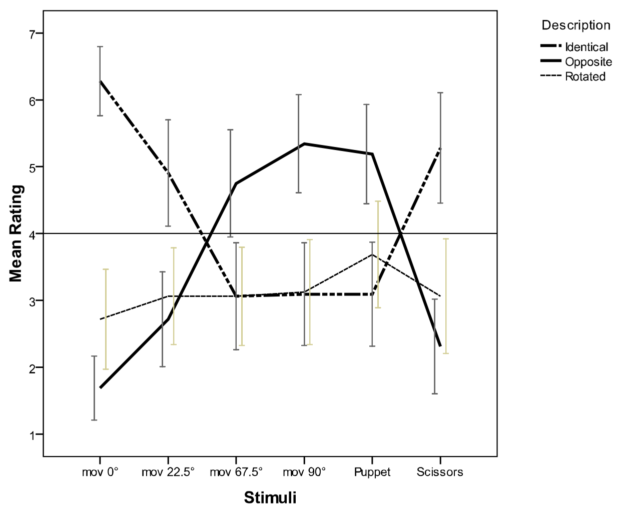

Figure 5.4 Average ratings attributed to the three phrases describing the reflection as, respectively, Identical, Opposite, or Rotated with respect to the real object or movement. (from Savardi, Bianchi & Bertamini, submitted).

The pattern of motion seen when the ball was moved parallel to the mirror was best described in the statement "the reflection moves in an *identical* direction to the real movement." This description was also rated as adequate (although significantly less adequate) when the white ball was moved at an angle of incidence of 22.5°. For these two dynamic conditions *opposite* was considered to be inadequate. When the white ball was moved at angles of 67.5° and 90°, participants described the reflection as moving *opposite* to the real movement. In these two conditions *identical* was deemed to be inadequate.

Rotation never entered the frame as an alternative description and this result definitively weakens the hypothesis (advanced by Bertamini, Hect & Spooner, 2003) that people think of the reflected world in terms of a 180° rotation around the plane surface of the mirror.

5.4 From what we see to what we expect reflections to do

We found that when people look in mirrors they perceive the relationship between reflected and real objects mainly in terms of identity and contrariety. If this was not the direct result of the experimental conditions but corresponds to what people really see when they look in a mirror, we might also expect to find traces of this in naive beliefs about reflections. In other words, if people were asked for example to predict how the reflection of an object in motion would move, what would they say?

There is a long tradition of research in Psychology into this types of questions, which are mainly addressed by means of paper-and-pencil tasks[1]. Errors are discovered in a large percentage of cases, even when predictions involve very simple and apparently easy (because regarding familiar experience) movements. Researchers have debated on whether the cause of these errors might be perception, reference to incorrect general naive theories that people have in mind regarding certain classes of phenomena, or rather the imagination of prototypical behavior derived (often in an imprecise way) from direct experience.

In the case of knowledge concerning mirrors and optics, it has been proved that although adults' knowledge of the basic laws of reflection is generally correct (namely they generally know that a reflected ray has the same angle or reflection as an incident ray), they are not able to rely on this knowledge when asked to resolve simple tasks. For example, when asked to predict *where* an observer would see themselves or a target object in a mirror, they do not think in terms of this law (which is known in 90% of cases) and in fact almost 50% of participants expect reflections to *appear on the opposite side* with respect to the direction of movement (Figure 5.5).

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[1] For example, many studies investigating naive beliefs about types of motion studied in classical mechanics, such as the trajectories and speed of falling objects, pendula, projectiles and wheel dynamics, find that systematic errors are made by adults (Bozzi, 1958, 1959; Frick, Huber, Reips & Krist, 2005; Hecht & Bertamini, 2000; Kaiser, Proffitt, D.R. & McCloskey, 1985; McCloskey, 1983; McCloskey, Caramazza & Green, 1980; Pittenger, 1989; Proffitt, Kaiser & Whelan 1990; Shaffer & McBeath, 2005).

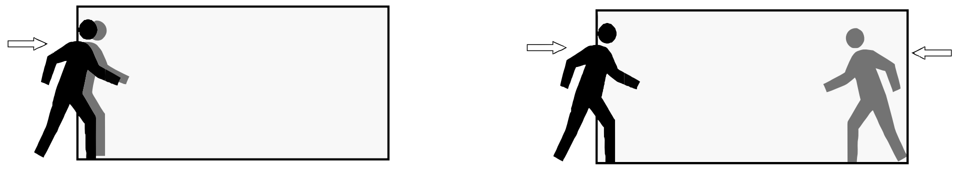

Figure 5.5 Representation of the correct location of the reflection (diagram on the left) and of the "location error" found by Bertamini et al., 2003 (diagram on the right). If asked to imagine a person approaching a mirror parallel to the mirror surface (black silhouette), almost 50% of undergraduate students predict that the reflection (the light gray silhouette) would appear on the opposite side (diagram on the right) rather than on the near side (diagram on the left).

If people recognize the behavior of reflections in terms of identity or contrariety, but at the same time they do not analytically understand why the reflection behave as it does, they might generalize the expectation of "identical" behavior beyond the respective conditions of validity. For example, in the case of a person moving parallel to the mirror, as in the experimental condition of Bertamini et al. (2003), the correct prediction should take into account the relationship between the x axes in Figure 5.1. It may be that people have in mind the behavior observed when approaching a mirror orthogonally (i.e. they focus on the relationship of contrariety between the vectors in the z axes) or that they recall an overall impression of identity and contrariety and this might lead exactly to the erroneous behavior found by Bertamini and colleagues.

Four different experiments were designed in order to study the hypothesis that predictions regarding how a reflection would move or how an object would be oriented, follow an understanding of reflections in terms of identity and contrariety (as presented in the previous sections of this chapter). In three studies we used paper-and-pencil tasks; in the other study predictions were made by approaching an imaginary mirror and imagining how the reflection would behave (Savardi, Bianchi & Bertamini, submitted). To keep the task simple, we focused only on movements along a straight line.

We considered different angles of incidence – from parallel to the mirror (0°), to orthogonal to the mirror (90°), through 22.5°, 45° and 67.5° – and movements towards or away from the mirror. In the two extreme conditions (i.e. movements parallel to the mirror and movements orthogonal to the mirror) predictions based on the rules that reflections "do the same" or "do the opposite" (respectively) would lead to the correct response. The correct patterns are, in fact, simply defined by the relationship between the x axes in the former case and between the z axes in the latter case (see Fig. 5.1 second row). When 22.5°, 45° and 67.5° angles of incidence are considered, the geometry becomes a little more complicated (see Figure 5.1 third row) because now the two identical and opposite vectors jointly contribute to the final movement and are the components of the resultant vectors.

Our findings revealed that the presence of contrariety as a global perceptual datum is evident to observers but acknowledgment of the exact correspondence between real and reflected movements is not as precisely focused on. Despite the fact that the movements were simple, in around 35% of cases people were unable to make the correct prediction. As expected, the task was easier when the prediction concerned an object moving parallel or orthogonal to the mirror: in these two conditions, errors were much less frequent, namely 24% for parallel motion and 15% for orthogonal motion.

The types of errors made by participants involved a simplification of the geometry of reflections. Participants either generalized the "identity pattern" (which is evident when looking at someone/something moving parallel to the mirror surface), or generalized the "opposition pattern" (which is evident when looking at someone/something moving orthogonal to the mirror surface). The number of errors based on the *expectation that reflections do the opposite* becomes greater as the angle of incidence increases (from min. 22.5° to max. 67°). This means that the "opposite" movement was predicted more frequently as the angle approached the orthogonal condition (90°) when *opposite* is in fact correct. This error was also typically accompanied by a localization error: people expected the reflection to move along the same line as the real vector, as shown in Figure 5.6. This further confirmed that people recall a pattern which is typical for orthogonal reflections, where in fact the two movements follow the same line.

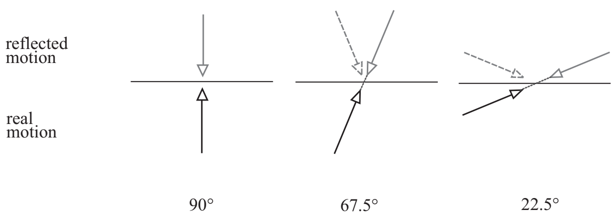

Figure 5.6 When the angle of incidence of the movement is orthogonal to the mirror (90°), the reflection moves along the same line as the real movement. This is not true for all the other angles of incidence (e.g. 67.5° and 22.5°, where the correct reflection is represented by arrows in broken lines). However, the most frequent error is to predict that the reflection would move opposite to the real motion, along the same line (gray solid arrows), generalizing the condition observed with movements at 90°.

The other error that we anticipated, i.e. generalizing and predicting that the reflection will do the same, even when conditions of validity of this rule are not fulfilled, was in general less frequent (around 17% of responses), did not increase or decrease depending on the angle of incidence and, interestingly, disappeared when the paper-and-pencil task was replaced with a more lifelike experimental condition. Making predictions when imagining that they were in front of a mirror led participants to make fewer errors in general than with paper-and-pencil tasks. However, a percentage of errors persisted (25%). In this case, they exclusively concerned the expectation that reflections would move *in the opposite direction* to the real person, *along the same line*. The descriptions given by participants for imagined movements[2] confirmed that they thought of the situation in terms of "opposite motion", both when the response was wrong and when it was right. Only when the movement of the real person was parallel to the mirror, did they describe the movement in the reflection as "identical".

5.5 Conclusion

The purpose of this chapter has been to show how an analysis of the perception of mirror images provides an interesting contribution to the analysis of contrariety as a perceptual phenomenon. The old debate on the mirror question had the merit of bringing to the forefront the egocentric right-left reversal which characterizes reflections on plane mirrors. At the same time, however, it did not succeed in identifying all the elements of contrariety which characterize the "real object - reflected object" configuration. This was because the debate was positioned between linguistics, physics and logic and thus an accurate phenomenology of the visual structures characterizing the various "real object - reflected object" configurations was not developed in that context.

A detailed analysis of the variations which are analytically recognizable in these visual configurations (Savardi & Bianchi, 2005), together with an investigation of the degree to which they are evident in direct perception (Bianchi & Savardi, 2008b; Savardi, Bianchi & Bertamini, submitted), led to the discovery that:

1. perception of identity and perception of contrariety are in *competition* and at the same time work together as a *couple* to characterize human experiences of mirror images. We have seen that the prevalence of either identity or contrariety depends on the way in which the object is asymmetrical and the position of the object with respect to the mirror;
2. for both recognition of identity and recognition of contrariety, the allocentric frame of reference (rather than egocentric) is decisive in determining perception.

Proof of this has been found both in direct descriptive tasks and when analyzing naive predictions of the expected behavior of reflections.

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[2] Stimulated by the question: how would you describe the motion that you have imagined? Would you say that the reflection is moving in the same direction, in an opposite direction, or rotated 180°?

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