ARTICLE

Mirrors and the mind

Marco Bertamini has some surprising reflections

Mirrors are familiar objects, but even simple questions about what they make visible to an observer are unexpectedly hard to answer correctly. Even harder is to think or judge what is happening on the glass surface. What psychological factors lie beneath these surprising difficulties?

questions

If you walk across a room parallel to a mirror, at what point can you see yourself?

Why does a mirror reverse left and right but not up and down?

resources

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> Then she took a mirror out of her apron and gave it to Peter, saying: 'Take this as a reward'. Now Simple Peter had never seen a mirror before and so, when he looked down and saw the reflection of the sky in his hands, he said: 'Have you given me the sky?'
> *Terry Jones – ' Simple Peter' s Mirror'*

Most people are fascinated by mirrors and reflections. This is not a new phenomenon: in ancient Rome, Seneca mocked the amount of money that Roman women were willing to pay for a mirror (for a cultural history of mirrors see Melchior-Bonnet, 2001).

Mirrors as objects remained small and expensive for centuries. But by the 16th century in Venice a new method was used of backing a plate of flat glass with a thin sheet of metal, producing high-quality mirrors. More recently, in the 19th century, the process of coating a glass surface with metallic silver was invented. Today, unlike in Roman times, mirrors are all around us, in houses, shops and cars. Planar (flat) mirrors in particular are very familiar objects.

Given that mirrors are ubiquitous, simply on the basis of experience one might expect most people to have a clear idea of what a mirror does. In particular they should know what becomes visible in a mirror when looking from different viewpoints because they have walked in front of a mirror many times. Indeed, in Terry Jones's story we laugh at simple Peter's misunderstanding of what a mirror is (no worries, he fully redeems himself by the end of the story).

Let us consider a simple question. Imagine a room with a square mirror. A top view is provided in Figure 1. The side of the mirror is about 1 metre long, and is attached in the centre of a long wall, at eye height. Now imagine that you have just entered the room through the door. Note that this is a situation not unlike everyday life. As you look towards the mirror will you be able to see yourself? Maybe not, but what if you move towards the mirror? How far do you have to walk towards the centre of the room before you will start seeing yourself? Many adults say that they would have to walk a bit but that they will start seeing themselves some distance before reaching the near edge of the mirror (Bertamini, Spooner & Hecht, 2003; Croucher et al., 2002). That makes some intuitive sense – surely what we see reflected in a mirror is more than just a one-metre wide tunnel and so the scene must extend to the left and the right.

In reality people must reach at least the near edge of the mirror to start seeing themselves. Light has to bounce off the object (the person in this case), hit the mirror, bounce back with the same angle as that of incidence, and then reach the eye of the observer. One could work out this answer on the basis of knowing that angles of incidence and reflection are the same, but everyday experience should also suffice. We often walk in front of mirrors and in every instance we need to be in front of them to see our own reflection.

I will refer to this type of error as an 'early' error, following the usage in the literature, but the important aspect here is that it is an overestimation of what one can see. The same overestimation happens when the question is about when one would start seeing an object, so it is not specific to seeing one's own reflection.

Here are some surprising things that we know about the early error:

- people only overestimate what they can see from the left or the right of a mirror, not from above or below, even though they probably have more

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experience of walking in front of a mirror from the left or the right than moving up or down;
- instead of an abstract question, the task can be made very concrete, as when walking in a real room with a covered up mirror on a real wall. This leads to an even greater overestimation than the paper-and-pencil task;
- there is no difference between psychology and physics students on the size of the effect (Bertamini, Spooner & Hecht, 2003; Croucher et al., 2002);
- the error seems to emerge in young adults and is absent in primary school children (Bertamini & Wynne, in press).

It seems, therefore, that some simple questions about what is visible in a mirror can be challenging. Something similar happens when we ask what can another person see in a mirror. For instance, most paintings that have a Toilet of Venus as the subject (and there are many, especially after Titian reintroduced this theme into Renaissance art) tend to place Venus next to a small mirror, held by herself or by a cherub, and the face of Venus is visible in the mirror. A classic example from Veronese is shown in Figure 2 (overleaf), and many more can be found in Miller (1998). Observers admiring the painting have the impression that she is looking at herself. However, as the viewpoint of the observer is very different from that of Venus, what the observer sees must differ from what Venus sees (Bertamini, Spooner & Latto, 2003). The tendency to claim that Venus is looking at herself in such scenes is known as the Venus effect.

The Venus effect does not imply any error on the part of the painter: on the contrary, the painters may cleverly exploit how perception works, as do directors. On television or in a movie the camera can be placed to one side, showing both the actor and the actor's reflection in a mirror. To share the same view as the actor the camera should really be behind the actor, but thanks to the Venus effect this is not necessary. This is fortunate because a camera behind the actor would not only show the back of the actor, it would also appear in the mirror. The actors on the other hand may not see themselves (they see the camera instead) or may not see themselves centred in the mirror, depending on the size of the mirror. An example where the positioning is chosen so as to centre the image of the face for the camera is the final scene of *Raging Bull*, in which LaMotta (Robert DeNiro) is talking to himself in front of his dressing room mirror.

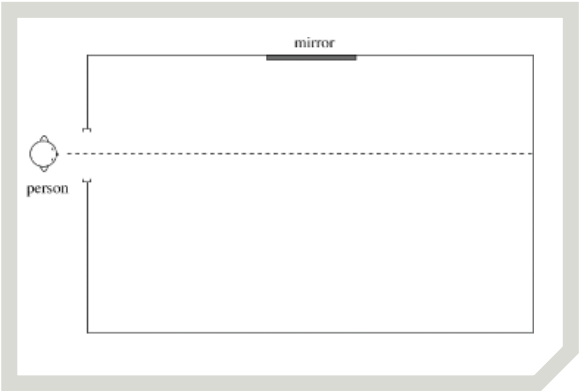

Figure 1. The person in the drawing walks through the door and across the room, at which point can she first see herself in the mirror?

So why do we all struggle when dealing with mirrors? To understand these errors it is useful to remember a few things.

Firstly, the illusion of depth of knowledge. This illusion is not specific to mirrors: in general, people have a feeling that they understand devices with far greater precision than they really do. Only when asked to fully explain something people realise the limits of their knowledge (Keil, 2003; Rozenblit & Keil, 2002). This illusion is particularly strong for mechanical devices like a can-opener or a bicycle. Many adults produce schematic drawings of bicycles that could not work, for instance because the chain joins the back and the front wheels (Lawson, 2006). Mirrors are not mechanical devices, but in common with bicycles they are familiar objects. Therefore, the confidence that people display in making (wrong) predictions about mirrors is probably related to the illusion of depth of knowledge.

Secondly, virtual objects are hard to imagine. We might think that as we look in the mirror what we see is an identical copy of ourselves (and everything else). In reality the copy is different in a subtle way – the real object and the virtual object are related the way that our right hand is related to our left hand. This difference is not conventional (it is not a matter of using different labels); for example, if I could remove my left hand and put it on the table it would still be possible to see that it is a 'left' hand (in the same way as a left glove would be recognisable as left). An important point is that this relationship is hard to picture

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Left and right

Why does a mirror reverse left and right but not up and down? (see Gregory, 1998). Richard Feynman is also known to have discussed it in detail. There is no controversy on the source of the problem, but disagreement on the best way to explain the answer. Consider the transformation that relates an object and its virtual copy. After the transformation what is up remains up, what is down remains down, but also what is left remains left and what is right remains right. For example, our left hand and the corresponding virtual object are both on our left. However, this left hand is now the right hand of the virtual person, because in that case we are using object-relative labels and the object has changed (real and virtual objects are different 3D objects). An American magazine years ago ran a contest to find the most succinct answer and the winner was: 'because up and down are absolute directions, while left and right are not'. However, everybody likes to explain this puzzle in their own words, and people will continue to enjoy it for a long time to come.

in our mind, we end up rotating the real objects to try and match the virtual objects. This cannot be done (because they are both 3D objects we would need to rotate them in 4D, which is beyond anybody's power of imagination). We are tempted by the idea that we could walk around a mirror and 'become' the virtual self, but this is a mistake. Therefore, it is in general difficult to rely on our power of imagination to picture what the scene in a mirror would look like even when we know exactly what the real objects look like (and where they are in the real world).

Finally, the projection is hard to see. If we could look at mirrors and then remember the image on the surface we could answer a number of questions about mirrors. But this option is not available because projections on a mirror are treated by the visual system like projections on transparent surfaces: neither can be judged accurately. I doubt that you will take my word for it, therefore you may check the studies in which we tried asking people to judge the size of projections on mirrors or on window panes (Lawson et al., 2007). Alternatively, to give you a quick idea, imagine that you are in your house, drinking coffee in your usual chair and looking out of the window at your Vespa (you can change the scenario to suit you). You have seen that image through the window countless times, so how big is the image of the projection of the Vespa on the glass of the window? That is, if you were to outline the Vespa with felt-tip pen on the window, while remaining in your chair (i.e. without changing the viewpoint), what is the size of the outline on the glass? I suspect that you cannot easily answer the question even though you know exactly what projection we are talking about, and you know that you have been exposed to it many times.

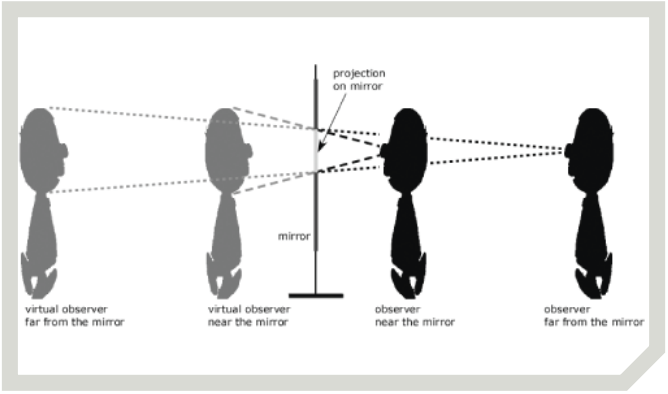

Figure 3. The fact that the projection of our own head remains half the size of the head from any distance is counterintuitive. This diagram should help because it shows the virtual observer, standing inside the mirror at the same distance as the observer outside it. Note that the projection on the mirror is the same from near or from far

In 1960 Ernst Gombrich wrote about a fascinating demonstration of the fact that we do not see the projection on a mirror surface, although he did not discuss it in these terms. The demonstration is the following. If you stand in front of a fogged up mirror in a bathroom, you can clear just enough space to see your face. You will then be surprised that the area that you cleared is rather small. It is in fact half (in height and width) of the physical size of your face. This is counterintuitive, as is the fact that the size of the projection does not change as one moves nearer or farther from the mirror. Note, however, that both of these facts are specific to our own body, or more precisely specific to a situation where the location of the viewpoint is the same as the location of the physical object that is reflected (Figure 3). Therefore, they do not apply to the projection of another person, as in the Venus effect for example.

In the special case when we look at our own face or body in a mirror, we tend to believe that the projection should be the same size as our face or body. However, when we consider a rather small mirror (the size of a pocket book), we also believe that we could see the whole of ourselves if we are allowed to move as far away as we want. The two beliefs are not compatible, so they cannot both be true. But they can both be false. The projection, as discussed above, is half the physical size, so we need a mirror at least that size to see ourselves in it.

It seems that what is on the surface of the mirror is hard to see and therefore hard to know anything about, but it is still interesting to see what people believe about it in the general case where target and observer do not coincide. We found that most people expect the size of the projected image to change if the target object is moved away from the mirror, but not if only the observer is moved away from the mirror. In reality the projection depends on both the location of the target and the location of the observer but it is interesting that we intuitively seem to regard the projection as only related to the target (Bertamini et al., 2008; Bertamini & Parks, 2005).

What we have seen, in summary, is that mirrors are amongst the most familiar objects in our environment, yet not only is the way that they work hard to predict but also we hold systematically wrong expectations about them. Underneath these surprising errors there is a combination of factors, including a general overconfidence in what we know about familiar objects, a problem with performing mental transformations that match real and virtual objects, and the fact that what is on the surface of the mirror is only a projection and therefore not something that we see in the same way that we see distal objects.

Figure 2. Veronese's *Venus at Her Toilette* (c.1582) is a good example of the Venus effect. Viewers may read the scene as Venus admiring herself, even though they are looking at the mirror from a very different viewpoint.

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