Review

The nature of visual self-recognition

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Visual self-recognition is often controversially cited as an indicator of self-awareness and assessed with the mirror-mark test. Great apes and humans, unlike small apes and monkeys, have repeatedly passed mirror tests, suggesting that the underlying brain processes are homologous and evolved 14–18 million years ago. However, neuroscientific, developmental, and clinical dissociations show that the medium used for self-recognition (mirror vs photograph vs video) significantly alters behavioral and brain responses, likely due to perceptual differences among the different media and prior experience. On the basis of this evidence and evolutionary considerations, we argue that the visual self-recognition skills evident in humans and great apes are a byproduct of a general capacity to collate representations, and need not index other aspects of self-awareness.

Reflecting on visual self-recognition

Visual self-recognition has long fascinated scholars partly because of its intuitive appeal as a potential indicator of self-awareness. Many humans regularly spend time in front of mirrors and invest efforts into improving their looks. Various other species adjust their appearance to impress potential partners and opponents or to camouflage, but they do not seem to take advantage of reflective surfaces in their efforts to do so. Fish sometimes show aggressive behavior towards their mirror image, although their brain responses differ compared to when they fight a real fish, which suggests that they recognize something unusual about the mirror [1]. Numerous species, including pigs [2] and New Caledonian crows [3], can use mirrors to find hidden objects. Great apes can even be observed using mirrors to examine body parts, such as their anal region, that they cannot otherwise see and their understanding was confirmed through a now widely used mirror mark test first developed by Gordon Gallup over 40 years ago [4]. In recent years, significant research efforts have been devoted to understanding the development, neuro-cognitive basis, and disorders of visual self-recognition [5–9]. Here, we highlight recent conceptual and methodological issues that are critical to interdisciplinary integration. In particular, it has become evident that behavioral and brain responses can vary considerably depending on the medium used to present images of self. We argue that these findings, when integrated with developmental and comparative data, suggest that successful performance in self-recognition tasks draws on a broader capacity to collate representations, rather than on general, context-independent self-awareness.

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The mirror mark test

Gallup exposed chimpanzees to a mirror before placing an odorless, tactile-free mark on the uppermost portion of their eyebrow ridge and ear while they were anaesthetized. Upon recovery, a mirror was reintroduced and their behavior observed. Self-directed responses to the marked areas significantly increased compared to control conditions without the mirror. Subsequent replications, typically using surreptitious marking rather than anesthetics, confirmed that chimpanzees can recognize themselves in mirrors [10]. Many species have subsequently been tested (Box 1), but only the closest relatives of chimpanzees (humans, gorillas, and orangutans) have so far provided independently replicated evidence of passing the mark test [11,12]. When using carefully matched criteria, chimpanzee and human infants develop the capacity for mirror self-recognition in a similar manner [13].

Although some signs of self-recognition, such as familiarity with one's image, are evident in two- to three-month-old infants [14], the mark test is not typically passed until over a year later. Using rouge or stickers to surreptitiously mark toddlers, researchers have repeatedly found that children begin to pass the test from 15 months of age; by 24 months most children pass [15–18]. Some diversity in pass rates has recently been reported from different cultures [19]. In one study on 16–21-month-olds, urban German and Indian children passed the test earlier than rural Indian and Nso children, leading the authors to conclude that this reflects an autonomy-supporting cultural context in the former and a relational cultural context in the latter [20]. Nonetheless, the basic ability seems to be universally acquired in toddlers. For instance, Bedouin children, even without previous experience with mirrors, were found to develop competence in the same way as Israeli children familiar with mirrors [21].

What does the mirror mark test measure?

In spite of its intuitive appeal, it has been controversial what the mirror mark test indicates [6,22–25]. Gallup argued that it measures self-awareness because one needs to be able to become the object of one's own attention to pass the test. He went on to argue that the task implies a self-concept, a capacity for introspection, theory of mind, and awareness of death [24]. In support of such rich interpretations, researchers have documented associations between the onset of mirror self-recognition and other purported indicators of self-awareness, such as use of personal pronouns, empathy, synchronic imitation, and embarrassment [20,26]. However, there is no direct evidence that supports links between self-recognition and death awareness or introspection.

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Box 1. Mirror self-recognition in diverse species

Many other primate species have been tested with this paradigm, but consistently fail [11]. Although monkeys may not confuse their mirror image with a social other [61], they have repeatedly failed the formal mark test, even after extensive exposure to mirrors [11,62]. However, occasional high-profile claims have been made about self-recognition in animals. First, pigeons were conditioned to peck on their own body in front of mirrors [63], but this behavior was not spontaneous and required extensive training. Curiously, such conditioning has not been successful when employed with capuchin monkeys [64]. Next, cotton-top tamarins were claimed to have passed the test when their distinctive white hair was died red [38]. However, these results were heavily critiqued [65] and could not be replicated by the original lead author [66]. Then, two bottlenose dolphins were argued to recognize themselves [67], but, because of their lack of hands, the dependent variable was not reaching for the mark as required in the standard task. Given their brain size and the frequency with which they naturally see their reflections as they jump out of the water, it would not be surprising if dolphins were capable of visual self-recognition. Replications of this study would be highly desirable. A few years later one of three Asian elephants tested was claimed to have passed the mirror mark test by reaching with its trunk towards the mark [68]. However, in an earlier study, elephants had failed [69], which highlights the need for independent replication. This is also required for the claim that two out of six tested magpies passed the mark test [70]. Although assertions about potential competences in various species continue to be made [71], they frequently fall short when examined critically [62]. Careful replications are hence essential. Only the great apes have thus far provided repeatedly replicated evidence of passing the mark test [11]. Even among the great apes, not all individuals pass. It is possible that some animals do not have the capacity (e.g., because of immaturity or old age) [72] or fail because of differences in attention, affect, or motivation [13]. Furthermore, experiments vary in terms of methodology and precise criteria [13].

Rich interpretations of the task have been repeatedly challenged by leaner accounts. Most prominently, Heyes argued that to pass the test one only needs an ability to distinguish feedback from other types of sensory input [23]. In other words, passing the test demonstrates nothing more than the capacity that allows animals to avoid bumping into things. This view dismisses mirror self-recognition as not indicating anything particularly interesting, but it fails to provide an alternative account for the current pattern of results. It does not explain why only a few species pass the test, even though many species evidently can distinguish feedback from other input in other contexts. Nor does it explain why human infants pass the test when they do, rather than at an earlier point in development, when they already clearly distinguish feedback from other input [27].

Between these extremes are accounts that claim the middle ground. For instance, it has been argued that passing the test indicates a developing concept of one's own face [28], that it indicates a present self-concept as opposed to one extended in time [22] or that it is just one of several indicators of a more general capacity to entertain and compare multiple models of the same thing [29]. Although there has been intense discussion about methodology and interpretation [6,13,25], few variations of the paradigm have been designed to resolve the debate.

A notable exception has been a series of experiments in which children were placed in a highchair and then marked on their leg, rather than their face [16]. Findings showed that toddlers are equally capable of recognizing their legs in a mirror as they are at passing the standard task, undermining theories that have placed special emphasis on cognition about faces [28]. In another two conditions, participants were slipped into baggy tracksuit trousers that were attached to the highchair and then presented with a mirrored view of their legs. In one of these conditions, before the legs were marked with a sticker, a tray that had blocked the direct view of their legs was removed for 30 seconds, in the other it was not. Although the toddlers saw the same mirrored image of baggy trousers in both conditions, they performed poorly without direct exposure and performed as well as in the standard task when they had the brief opportunity to view what they were wearing. These results strongly suggest that young children form a mental expectation of what they look like and can do so rapidly [16].

The mirror mark test, therefore, measures more than Heyes' lean account proposes. What children saw in the mirror was identical in these last two conditions of the leg recognition study, yet they passed only when they had an opportunity to update their expectations about their physical appearance. So there is more to passing the task than distinguishing feedback from other sensory input. In a sense, those who pass may be said to be self-aware about what they currently look like. However, this need not mean that they are self-aware in other respects, as Gallup's rich account conjectures – nor even that they are entirely realistic with their expectations (Box 2). Individuals can clearly be self-aware about one facet (e.g., an aspect of one's personality), while being completely ignorant about another (e.g., some weaknesses).

In sum, we recommend staying close to the data when interpreting relevant evidence. The leg self-recognition findings support the moderate account that the test reflects the capacity to generate and compare multiple models of the same thing [13,29,30]. By comparing an expectation about one's physical appearance with current perceptions of a reflection, inconsistencies, such as the mark, can be noted and motivate exploration. Next, we consider whether systematically varying the feedback can uncover deeper aspects of self-awareness.

Self-recognition and diverse feedback

A key ingredient of human identity is the capacity to travel mentally in time and reconstruct experiences of the past and imagine future events [31,32]. Povinelli and colleagues [22] created a delayed self-recognition test in which children were shown a three-minute-old video recording of themselves being marked with a sticker. Young children who could long recognize themselves in mirrors did not retrieve the sticker from their fringe, even after repeated questioning. Only from approximately age four did children pass [22,33]. Povinelli subsequently suggested that the mirror mark task is an indicator of a 'present self', whereas passing this delayed version demonstrates a 'temporally extended self' (and this developmental asynchrony has since inspired diverse research on developmental disorders [34,35]).

If the delay task really measures the emergence of a temporally extended self, further experimental manipulations should be able to track development in more detail.