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Mirror Self-Recognition Beyond the Face

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Three studies ($N = 144$) investigated how toddlers aged 18 and 24 months pass the surprise-mark test of self-recognition. In Study 1, toddlers were surreptitiously marked in successive conditions on their legs and faces with stickers visible only in a mirror. Rates of sticker touching did not differ significantly between conditions. In Study 2, toddlers failed to touch a sticker on their legs that had been disguised before being marked. In Study 3, having been given 30-s exposure to their disguised legs before testing, toddlers touched the stickers on their legs and faces at equivalent levels. These results suggest that toddlers pass the mark test based on expectations about what they look like, expectations that are not restricted to the face.

One of the most popular yet hotly debated tests in early cognitive development is the ''mark test of mirror self-recognition'' (Amsterdam, 1972; Gallup, 1970). This test involves surreptitiously marking an individual's face so that the mark cannot be seen directly. Individuals are subsequently presented with a mirror and their reaction to the reflection is observed (the task is therefore also known as a ''surprise-mark test''; Suddendorf, 1999). There is a clear developmental trend in infants' responding. Children under 18 months typically ignore the mark whereas older children typically ''pass'' this task by investigating their own face in search of the mark (Amsterdam, 1972; Lewis & Brooks-Gunn, 1979; Nielsen & Dissanayake, 2004). What is not so clear is what this change in behavior signifies.

It has been widely argued that the surprise-mark test measures self-recognition, and passing it is seen as evidence that the child knows what he or she looks like (Amsterdam, 1972; Anderson, 1984a; Bertenthal & Fischer, 1978; Courage & Howe, 2002; Lewis & Brooks-Gunn, 1979; Nielsen, Dissanayake, & Kashima, 2003). Yet, such an interpretation of the task is by no means universally accepted. On the one hand there are ''lean'' proposals, such as the view that passing the test only demonstrates an individual's capacity to ''distinguish, across a fairly broad range, sensory input from the physical state and operations of its own body from sensory inputs originating elsewhere'' (Heyes, 1998, p. 105). On the other hand there are ''rich'' interpretations, such as the claim that the test indexes individuals' ability to introspect and reflect on their own mental states (Gallup, 1983, 1998; Gallup, Anderson, & Shillito, 2002).

Add to the mix a host of intermediate proposals emphasizing, for example, the development of an interest in and concept of one's own face (e.g., Neisser, 1995), the development of a physical, as opposed to a mental, self-concept (e.g., Povinelli, 1995, 2000), or the maturation of more general cognitive capacities such as the ability to construct multiple mental models (Asendorpf, 2002; Nielsen & Dissanayake, 2004; Perner, 1991; Suddendorf & Whiten, 2001), and it becomes clear that the interpretation of this seemingly simple task is plagued by controversy. We cannot do justice to all contributions here. For our purpose, we want only to note that in spite of the wealth of proposals and task analyses, surprisingly little effort has been devoted to developing designs that can test competing interpretations. In Study 1, we describe research designed to test whether the face has a unique role in self-recognition.

To date, research using the mirror test has focused on marking the face. This focus is partly due to the apparent practical requirement of needing to mark a part of the body that cannot be seen without the aid of a mirror. But the face is also often regarded as the primary physical embodiment of the self (Cole, 1997; Harter, 1983; Kircher et al., 2001; Lewis & Brooks-Gunn, 1979), and therefore a number of theorists who discuss the surprise-mark task have concentrated on the need to identify one's own facial features in order to pass the test (Anderson, 1984a; Hart

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& Fegley, 1994; Lewis & Brooks-Gunn, 1979; Neisser, 1993, 1995, 1997).

Neisser (1993, 1995), for example, argued that children do not pass the test until the second year because before this age the face is not an important component of their ''ecological self.'' Infants as young as 6 months can discriminate between their own face and the face of a peer, based on familiarity of their own image (Bahrick, Moss, & Fadil, 1996; Legerstee, Anderson, & Schaffer, 1998; Rochat & Striano, 2002). According to Neisser, it is only later in development, when infants notice that their facial appearance matters to other people, that they use the mirror image to gain information about their own appearance. Because one's own face is not directly observable, such an account has certain plausibility. Thus it may be that it is only once infants have acquired a concept of what their own face looks like that they take note of the features of their own face, and care when their mirror image does not match their mental image (as is the case when their face has a new, unexpected ''spot'' on it).

The goal of Study 1 was to test the hypothesis that performance on the surprise-mark task reflects changes in cognition about one's own face. We presented toddlers with an unexpected mark on another body part that they could not see directly: their legs. If toddlers exhibit similar levels of mark-directed behavior in the leg self-recognition task as they do in the face self-recognition task, it reduces the likelihood that cognitions related to the face per se lie at the heart of performance on the classic surprise-mark task.

In Studies 2 and 3 we used the novel leg mirror self-recognition task to investigate the widely held assumption that individuals who pass the surprise-mark test do so because they know what they look like. To investigate mark-directed behavior when the mirror image does not match toddlers' expectations of what they look like, in Study 2 we surreptitiously placed toddlers in a pair of novel pants before administration of the leg recognition test. In Study 3, to test directly whether knowledge of what one looks like is necessary for mirror self–recognition, we again placed toddlers in novel pants, but provided them with the opportunity to see that they were now wearing the new pants before testing. Each study included children aged 18 and 24 months. These ages were chosen as past research has indicated that toddlers begin to pass the standard face recognition test from around 18 months of age and that a majority pass the task by 24 months (Amsterdam, 1972; Courage, Edison, & Howe, 2004; Lewis & Brooks-Gunn, 1979; Lewis, Brooks-Gunn, & Jaskir, 1985; Nielsen & Dissanayake, 2004; Schneider-Rosen & Cicchetti, 1991).

Study 1

Method

Participants

The final sample of 48 toddlers included 13 girls and 11 boys at 18 months of age ($M = 18$ months 5 days; age range 17 months 16 days to 18 months 20 days) and 14 girls and 10 boys at 24 months of age ($M = 24$ months 8 days; age range 22 months 9 days to 25 months 6 days). Data from an additional 21 toddlers were not included: 14 (ten 18-month-olds and four 24-month-olds) because of fussiness before completion of testing and 7 (five 18-month-olds and two 24-month-olds) because they failed the posttest control of the Leg Recognition test outlined below (these 7 toddlers also failed the Face Recognition test).

Toddlers' names were taken from birth announcements of a local newspaper or from an existing subject pool. Caregivers were contacted via mail and telephone and anyone who volunteered to participate did so. Most toddlers were White, and were from middle-class English-speaking families living in metropolitan suburbs surrounding the university. All toddlers received a small gift for participating.

Apparatus and Procedure

On arrival at the university, toddlers and their primary caregiver were escorted to a room where the toddlers could play to warm up. After this they were brought to the testing room. Each toddler was tested individually and accompanied by the caregiver throughout the session. Caregivers sat on a chair to the side of their toddler, where they could not be seen in the mirror, and were asked not to influence their child during the study. All sessions were videotaped using a camera that was positioned behind the toddlers in order to capture their actions in the mirror. Bright, sparkling, circular stickers 5 cm in diameter were used to mark the toddlers in both mirror self-recognition tests described below. The Leg Recognition task was always administered first to avoid potential transfer from the Face Recognition task. Because the face self-recognition task is well established, previous published results could be used to judge the typicality of performance on this second test.

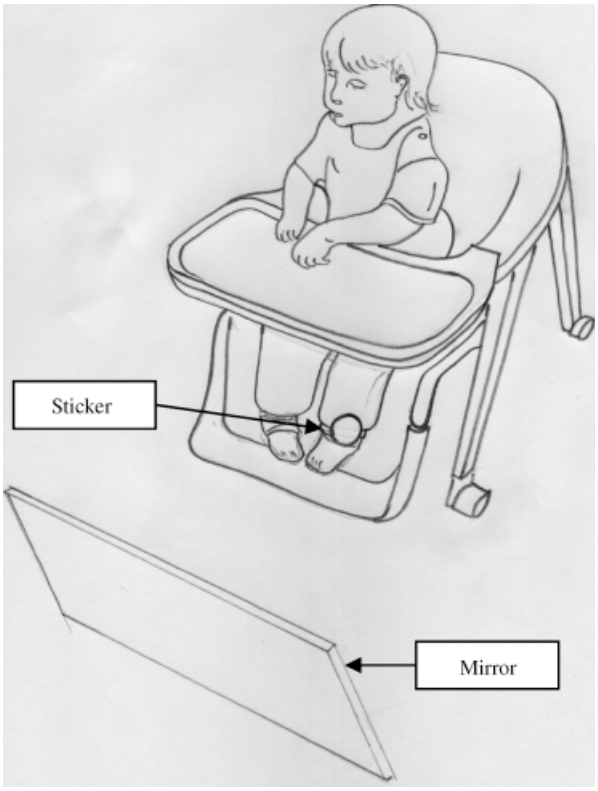

Figure 1. Experimental layout for the Leg Recognition test of Study 1.

Leg recognition. Toddlers were placed in a high chair that was lowered such that their feet were at ground level. A plastic occluder was secured around the toddlers' waist ensuring that they could not directly view their own legs or feet. The chair was positioned facing a covered mirror (120 cm × 48 cm) approximately 75 cm away. The mirror was placed on its horizontal edge so that, when uncovered, the toddlers could see only their legs and feet in the mirror (see Figure 1 for the experimental layout). The test was preceded by a familiarization period and, if the toddler failed the surprise-mark test, followed by a control test described below. At each stage if the toddler did not appear to fixate on the image the experimenter pointed in the general direction of the mirror and said, ''Look at that.''

Once the toddler was comfortable and settled in the seat, the mirror was uncovered for a 30-s familiarization period and then the mirror was covered again. This provided a baseline of the toddlers' tendencies to touch or attempt to touch their legs while viewing them in the mirror. The toddlers did not spontaneously touch their legs during this phase.

For the Leg Recognition test, toddlers were engaged in a distracting game so that the experimenter could surreptitiously affix a bright sticker to their feet (randomly to the left or right foot). All toddlers were tested in the clothes they were wearing on the day of testing. Their shoes were removed before testing while they were in the warm-up room. They remained in socks throughout testing to ensure that there were no tactile cues as to the placement of the sticker. To ascertain that the toddlers were unaware of the sticker, the toddler and experimenter continued to play for a further 30 s. None of the toddlers showed any signs of noticing the sticker placement during this time. Subsequently, the mirror was uncovered for 30 s. The sticker could be clearly seen in the mirror once the mirror was unveiled. As toddlers may notice the sticker but be uncertain as to whether they are allowed to, or expected to, reach for it, the experimenter said, ''Look at that. Can you get it for me?'' while pointing toward the mirror. If the toddler responded by removing the sticker, the toddler was classified as passing the Leg Recognition test (see the Coding section).

Toddlers who failed to reach for the sticker were given a posttest control. The experimenter played with the toddler for approximately 60 s. The occluder was then removed from the toddlers' waist, thus permitting them to directly see their legs and, hence, the sticker. If the toddler failed to remove the sticker after 30 s, the experimenter pointed toward the toddler's feet in the general direction of the sticker and said, ''Look at that. Can you get it for me?'' Toddlers who failed to retrieve the sticker in this control condition were replaced, because their retrieval failure may have been due to a lack of motivation (i.e., a false negative).

Face recognition. After the Leg Recognition test, the toddler remained in the high chair and the covered mirror was placed on its vertical edge (hence providing a full body view). While the toddler was engaged in a game with the experimenter, she rubbed the toddler's forehead, surreptitiously fixing a sticker (of a different color to the sticker used in the Leg Recognition test) around the bangs area. Marking is often done with rouge, but stickers have been used as a successful alternative (Nielsen & Dissanayake, 2004; Povinelli, Landau, & Perilloux, 1996; Suddendorf, 1999). To ensure that the toddler was unaware of the sticker, the toddler and experimenter continued to play with the toy for a further 30 s. No toddler noticed the sticker during this period. Subsequently, the mirror was uncovered and the toddler was given 30-s exposure. As with the leg test, to avoid motivational issues the experimenter said, ''Look at that. Can you get it for me?'' while pointing toward the mirror in the general direction of the sticker.

Coding. Performance on Leg Recognition and Face Recognition tasks was coded from videotape. Coders judged whether the toddler attempted to reach for the sticker during the pretest period, the test period, and (if applicable) the posttest period. For the Leg Recognition test, toddlers could negotiate the occluder to reach their legs in a number of ways. For example, they could reach down between the occluder and their legs, they could reach around the side of the chair, or they could lift their legs up straight so that their feet poked out from beneath the occluder. The dependent variable was retrieval of the sticker or reaching to within 2 cm of the sticker. A second independent coder coded 20 randomly selected toddlers (10 from each age group). There was 100% agreement between the two coders on each measure.

Results and Discussion

There were no gender differences on any of the variables measured here for either age group. Therefore, gender was not considered in further analyses. The 48 toddlers in the final sample did not attempt to reach for the sticker during familiarization or pretest marking periods. Of the 24-month-olds, 88% passed the Leg Recognition test and the same percentage passed the Face Recognition test. Among the 18-month-olds, 42% passed the Leg Recognition test and 50% passed the Face Recognition test (see Table 1). These percentages are similar to published results on the Face Recognition test (e.g., Lewis et al., 1985: 48% for 18-month-olds and 70% for 24-month-olds; Nielsen & Dissanayake, 2004: 64% for 18-month-olds and 92% for 24-month-olds; Schneider-Rosen & Cicchetti, 1991: 32% for 18-month-olds and 73% for 24-month-olds). In line with previous work, older toddlers were more likely to pass the Face Recognition task than were the younger toddlers ($\chi^2(1) = 7.86$, $p = .005$), and the same was true for the new Leg Recognition task ($\chi^2(1) = 11.02$, $p = .001$).

For both age groups, the majority of toddlers (83%) performed consistently across the two conditions (i.e., either passed both tests or failed both tests). Of the 24-month-olds tested, 83% passed both tests. One passed the Leg Recognition test but failed the Face Recognition test and one showed the opposite pattern. For 18-month-olds, the percentage passing both tests was 33%. Four 18-month-olds failed the Leg Recognition test but passed the Face Recognition test; two passed the Leg Recognition test but failed the Face Recognition test. The number passing one test but failing the other was not significantly different from those showing the opposite pattern by binomial test. The similar performance levels were observed in spite of the Face Recognition test always being administered after the Leg Recognition test. One might have expected that a second surprise-mark test would yield better performance because of transfer from the first, or alternatively that toddlers might be fatigued or unmotivated to retrieve another sticker in the second mark test. Within both age groups, the levels of performance on the two tasks were similar. There is therefore little reason to suggest that the new test of Leg Recognition was easier or more difficult than the traditional face task—it seems to measure the same thing. Thus, the argument that developments specific to processing one's own face enable toddlers to pass the task is put into question.

So how do toddlers pass these tasks? Do they know not just what their face looks like, but also what their legs look like? What they know about their legs might differ substantially from what they know about their face. Unlike one's face, the appearance of one's legs can usually be directly examined. Furthermore, and most importantly, although the face reasonably consistently retains its discriminative features, the appearance of one's legs depends foremost on what one is wearing that day.

Table 1
Numbers and Percentages of Toddlers at 18 and 24 Months of Age Passing the Leg Recognition and Face Recognition Tests of Studies 1, 2, and 3

		18 months		24 months	
Study	Task	*N* (of 24)	%	*N* (of 24)	%
Study 1	Face Recognition test	12	50	21	88
Study 2	Face Recognition test	14	58	21	88
Study 3	Face Recognition test	7	29	22	92
Study 1	Leg Recognition test	10	42	21	88
Study 2	Leg Recognition in Novel Pants (No Exposure) test	3	13	7	29
Study 3	Leg Recognition in Novel Pants (Brief Exposure) test	7	29	19	79

Remember, the toddlers were tested wearing their pants and socks. Therefore, to retrieve a sticker from one's legs by matching an image of one's expected appearance with the marked image in the mirror, the toddlers would have to have a memory of what they are currently wearing. Given the equivalence in performance on the Leg Recognition and Face Recognition tasks, the tests may measure the emergence of a ''this is what I look like'' concept—a concept that is not static, but one that is constantly updated and includes what one is currently wearing. This may be called the ''feature matching'' account of mirror self-recognition and reflects the view outlined previously that toddlers who pass the surprise-mark test know what they look like.

If toddlers pass the surprise-mark test by matching the image in the mirror to a mental image of what they expect themselves to look like, one would reasonably expect toddlers to fail a mark test in which they are presented with a mirror image that does not match their expected appearance. In Study 2 the current paradigm was adapted to test this.

Study 2

Method

As with Study 1, toddlers were placed in a high chair that had a plastic occluder secured around their waist (thereby ensuring that they could not directly view their own legs or feet). However, in Study 2, when the toddlers were placed in the high chair, their legs and feet were surreptitiously slipped into a pair of loose-fitting sweatpants. By placing the toddlers in sweatpants, it was possible to present them with an image that retained all the regular perceptual properties of mirrors and had the general appearance of legs (i.e., there were two separate pant legs that were oriented vertically, moved independently, and were located in an anatomically appropriate position) but did not match the specific features of the toddlers' own legs. This allowed a direct test of the ''feature matching'' account of mirror self-recognition, which predicts that toddlers will fail to reach for the sticker in the Leg Recognition in Novel Pants (No Exposure) test now that no cues to leg identity are available.

Participants

Thirteen girls and 11 boys at 18 months of age ($M = 18$ months 13 days; age range 17 months 18 days to 19 months 0 days) and 13 girls and 11 boys at 24 months of age ($M = 24$ months 16 days; age range 23 months 11 days to 25 months 15 days) were included in this study. Data from an additional 23 toddlers were not included: nine 18-month-olds and four 24-month-olds because of fussiness before completion of testing and ten (eight 18-month-olds and two 24-month-olds) because they failed the posttest control of the Leg Recognition in Novel Pants (No Exposure) task described below. Participants were predominantly White, from middle-class English-speaking families, and were recruited as in Study 1.

Apparatus and Procedure

All toddlers were tested first for Leg Recognition in Novel Pants (No Exposure) and second for Face Recognition following the procedure outlined in Study 1.

Leg Recognition in Novel Pants (No Exposure). A pair of child's sweatpants was sewn into a bedsheet and the sheet was fixed into the high chair used in Study 1. When toddlers were placed in the high chair, they were surreptitiously slipped into the pants. The pants were loose fitting and sewn shut at the feet (i.e., the toddler's feet could not protrude out of the pants). The sheet and the inner lining of the pants were a different color (beige) to the outsides of the pants (gray). This ensured that the toddlers could not match the color of the parts of the pants they could directly see at their waist to the color of the pants shown in the mirror. Once toddlers were comfortably sitting in the chair, the Leg Recognition in Novel Pants (No Exposure) test (herein referred to as the No Exposure test) was administered following the precise same procedure, and comprising the exact same distinct stages, as the Leg Recognition test introduced in Study 1. This was again followed by administration of the Face Recognition task, administered identically to the procedure outlined in Study 1. Coding was conducted as in Study 1. A second independent coder coded 20 randomly selected toddlers (10 from each age group). There was 100% agreement between the two coders on each measure.

Results and Discussion

The 48 toddlers in the final sample did not attempt to reach for the sticker during the familiarization or pretest marking periods. The percentage of 24-month-olds who passed the Face Recognition tests was again 88%; however only 29% of these toddlers passed the No Exposure version of the Leg Recognition test. A similar pattern was observed among the 18-month-olds: 58% passed the Face

Recognition test but only 13% passed the No Exposure test (see Table 1). Fourteen 24-month-olds failed the No Exposure test yet passed the Face Recognition test, but none showed the opposite pattern (binomial test, $p < .001$). Eleven 18-month-olds failed the No Exposure test but passed the Face Recognition test, but none showed the opposite pattern (binomial test, $p < .001$). This means that the No Exposure test was more difficult than the Face Recognition test for both age groups.

The No Exposure test was also more difficult than the original Leg Recognition test introduced in Study 1. The number of toddlers passing the No Exposure test in Study 2 was significantly lower than the number passing the Leg Recognition test in Study 1 for both 24-month-olds (7 and 21, respectively, $\chi^2(1) = 16.80$, $p < .001$) and 18-month-olds (3 and 10, respectively, $\chi^2(1) = 5.17$, $p = .023$). This suggests that if the mirror image does not meet their expectations about what they currently look like, the majority of toddlers will not pass the test.

There is, however, a viable alternative to this interpretation. One way for toddlers to form the connection between themselves and their reflection would be for them to move their legs while looking at the image in the mirror. Indeed, several proposals have emphasized that this type of contingency matching, the matching of proprioceptive and visual input rather than matching the mirror image to what one expects one to look like, is at the heart of the surprise-mark task (Mitchell, 1993, 1997, 2002; Parker, 1991; Povinelli, 2000). Also, adults tend to use this strategy when determining the relatedness of external images to the self (e.g., van den Bos & Jeannerod, 2002), and there are reasons to suppose that contingency matching is salient for young children as well. Long before children commonly pass the surprise-mark test (as early as 4 months of age), infants can discriminate images of self and other on the basis of contingency information. They look reliably longer at noncontingent video images of the moving legs of same-aged peers compared with contingent images of their own legs (Bahrick & Watson, 1985; Rochat & Morgan, 1995; Schmuckler, 1996). Proprioceptive–visual matching may provide important clues for self-recognition (Gergely, 1994; Mitchell, 1993).

In the No Exposure test, we altered the toddlers' appearance by surreptitiously placing them in loose-fitting pants. It is possible that the pants somehow disrupted the contingency match between movements the toddlers felt themselves making and the movements they saw in the mirror. Hence, toddlers may have failed to reach for the sticker in the No Exposure test because of imperfect proprioceptive–visual matching opportunities. If, by contrast, toddlers failed the No Exposure test because of the incongruence between the mirror image and their expected self-image, one could reasonably expect them to pass this test if given the opportunity to realize that they are now wearing loose-fitting gray pants. We tested this expectation in Study 3.

Study 3

Method

As in Study 2, as toddlers were placed in the high chair, their legs and feet were slipped into a pair of loose-fitting sweatpants. In contrast to Study 2, when the toddlers were first placed in the chair, the plastic occluder was not yet secured around their waist. Because the occluder was not yet in place, toddlers could directly see that they were now wearing the sweatpants. This provided them with an opportunity to update their concept of what they look like. If the ''feature matching'' account of mirror self-recognition is valid, toddlers should now reach for the sticker in this ''brief exposure'' version of the novel pants test.

Participants

The final sample of 48 toddlers included 12 girls and 12 boys at 18 months of age ($M = 17$ months 26 days; age range 17 months 1 day to 19 months 4 days) and 9 girls and 15 boys at 24 months of age ($M = 24$ months 13 days; age range 23 months 10 days to 25 months 3 days). Data from an additional 19 toddlers were not included: 17 (six 18-month-olds and eleven 24-month-olds) because of fussiness before completion of testing, one 18-month-old due to parental interference during testing, and one 18-month-old because of failure to pass the posttest control of the Leg Recognition in Novel Pants (Brief Exposure) task outlined below. Participants were predominantly White, from middle-class English-speaking families, and were recruited as in Study 1.

Apparatus and Procedure

All toddlers were tested first for Leg Recognition in Novel Pants (Brief Exposure) and second for Face Recognition following the procedure outlined in Studies 1 and 2.

Leg Recognition in Novel Pants (Brief Exposure). The apparatus was identical to Study 2 except that when the toddlers were first placed in the chair the

occluder was not positioned around their waist. The toddlers could therefore directly see that their legs and feet were now in the pants. Toddlers were given 30 s to familiarize themselves with being in the pants. After 30 s the occluder was fixed around the toddlers' waist, preventing them from looking directly at their legs as was done in Study 2. The test was then administered precisely following the procedure of Study 2. Coding was conducted as in Studies 1 and 2.

Results and Discussion

The 48 toddlers in the final sample did not attempt to reach for the sticker during the familiarization or pretest marking periods. Similar to performance in the previous studies, 92% of 24-month-olds passed the Face Recognition test and 79% passed the Leg Recognition in Novel Pants (Brief Exposure) test (herein referred to as the Brief Exposure test). On the Face Recognition test, 18-month-olds performed relatively poorly: only 29% passed. The same percentage passed the Brief Exposure test.

For the 24-month-olds, 19 toddlers passed both tests and 2 failed both. Three passed the Face Recognition test but failed the Brief Exposure test. Among the 18-month-olds, 3 toddlers failed the Brief Exposure test but passed the Face Recognition test and 3 showed the opposite pattern, and this was not significant by the binomial test. The Brief Exposure version of the Leg Recognition test was therefore no more difficult than the Face Recognition test.

As Table 1 shows, the number of 18- and 24-month-olds passing the Leg Recognition test was greater in the Brief Exposure version of the task compared with the No Exposure version used in Study 2. Significantly more 24-month-olds passed the Brief Exposure test of Study 3 than the No Exposure test of Study 2 (19 and 7, respectively), $\chi^2(1) = 12.08$, $p = .001$. This means that for the 24-month-olds, 30-s exposure to the novel pants allowed them to recognize the mirror image as their own legs. For the 18-month-olds, 7 passed the Brief Exposure test and three passed the No Exposure test. This comparison was not significant, perhaps because the rates of self-recognition in Study 3 were low in both conditions, resulting in low power for this comparison.

For the 24-month-olds, at least, it seems unlikely that failure in the Study 2 No Exposure task was entirely due to disturbances in proprioceptive–visual matching, or indeed anything else inadvertently peculiar about the pants. Some toddlers who passed the No Exposure test may have done so by matching their own felt movements to the movements made by the image in the mirror. However, sticker touching increased in Study 3 when there was a match between the image in the mirror and the mental image toddlers had of their expected appearance. Because exposure to the new pants was only 30 s in duration, it appears that this image can be rapidly updated.

General Discussion

The present studies investigated mirror self-recognition in 18- and 24-month-old toddlers using a novel variation of the surprise-mark test. In Study 1 toddlers performed equivalently on the novel Leg Recognition test and the standard Face Recognition test. These results rule out one type of explanation. Theories that have emphasized the special status of the face in explaining task performance, be it because the face is seen as the primary physical embodiment of the self (cf., Legerstee, 1998), because it is a body part that is not directly observable (Gergely, 1994; Mitchell, 1993, 1994), or because children first have to learn about the significance of their facial appearance (Neisser, 1993, 1995), do not explain why toddlers perform equivalently when the mark is on a more humble, usually directly observable body part: their legs. We can hence reject these proposals.

The results of these three studies also speak to the question of whether children pass the surprise-mark test based on an expectation of what they look like. Toddlers in Study 1 and Study 3 passed the Leg Recognition and Brief Exposure tests at similar rates to the Face Recognition tests. In contrast, toddlers in Study 2 performed poorly on the No Exposure test relative to the Face Recognition test. The No Exposure test was the only task in which there was no correspondence between what toddlers could have expected to see and what was shown in the mirror. This suggests that there needs to be some match between expectation and reflected appearance to enable them to deduce the connection between their mirror image and themselves.

Approximately 20% of toddlers, however, passed the test in the No Exposure condition in spite of the mismatch between the mirror reflection and what they could have expected their legs to look like. Hence, at least some toddlers may have used other cues, for instance by matching directly perceivable objects, such as the chair, or by proprioceptive–visual matching, to pass surprise-mark tests. Such strategies, though, cannot explain the differences in performance between the No Exposure and Brief

Exposure versions of the test. The Brief Exposure test was passed by 24-month-olds at rates significantly higher than the No Exposure test. The performance of 18-month-olds also improved when they were given brief exposure to the novel pants; however the increase was not statistically significant, possibly owing to the low rates of mark-directed behavior in this age group in both conditions of Study 3. This pattern suggests, for the 24-month-olds at least, that toddlers have a rapidly updatable expectation of what they look like from the outside that allows them to recognize the sticker as being on their own legs. The task does seem to measure what it was originally supposed to measure: self-recognition.

Our data support the proposal that passing the surprise-mark test "confirms that the participant has some mental representation of his or her appearance . . ." (Wheeler, Stuss, & Tulving, 1997, p. 334). However, the ability of toddlers to match their mental self-image to external representations of themselves is variable under different conditions, because seemingly minor deviations from mirrored feedback have dramatic effects on toddlers' performance on the surprise-mark test. Whereas the vast majority of 24-month-olds pass the standard mirror task, pass rates on live video versions of the surprise-mark test drop below 50% (Johnson, 1983; Simcock, Suddendorf, & Nielsen, 2004; Vyt, 2001). When children are tested with delayed video images, it is not until around 4 years of age that they consistently pass (Povinelli et al., 1996; Suddendorf, 1999). The apparent problems young children have with passing video versions of the surprise-mark test may lead one to question how specific or detailed their mental self-image is (although these problems may also reflect their difficulties with the medium; Suddendorf, 1999, 2003; Troseth, 2003; Troseth & DeLoache, 1998). Systematic investigation of the effect variations in temporal and feature information have on performance on the surprise-mark test might help answer this question.

The leg self-recognition task developed here has the potential to inform debate over the performance of other species on the surprise-mark test. For example, despite being able to use a mirror for object location tasks, monkeys consistently fail the standard face test (Anderson, 1984b). However, a potential problem in implementing this test with monkeys is that in most species a direct stare is treated as a threat and the avoidance of eye contact is common (Andrew, 1963; Kalin & Shelton, 1989; Kummer, 1967). Monkeys may fail to evince mirror self-recognition because the immediate reaction of these animals, when presented with a mirror, is to avoid staring at the reflection and, hence, they do not become familiar with their own image (Hauser, Kralik, Botto-Mahan, Garrett, & Oser, 1995). A similar argument has been raised to explain the low level of mirror self-recognition found in gorillas when compared to the other great apes (Shillito, Gallup, & Beck, 1999). Given the present results, these hypotheses could be tested by presenting monkeys and gorillas with a Leg Recognition task analog to the one we developed for Study 1.

From 4 months of age infants can discriminate between video images of themselves and images of others, based on both feature information (Bahrick et al., 1996; Legerstee et al., 1998; Rochat & Striano, 2002; see also Nielsen et al., 2003) and contingency matching (Bahrick & Watson, 1985; Rochat & Morgan, 1995). In spite of these early abilities of discrimination, it takes another year before toddlers begin to pass the surprise-mark task in mirrors. Something develops between 4 and 18 months. The results of the current studies suggest that, at a minimum, what develops is the ability to compare, and identify inconsistencies between, a mental image of what one currently looks like and one's mirror image. In our studies, some 18-month-olds and the majority of 24-month-olds found a sticker on themselves when the reflection was in line with what they could have expected themselves to look like, even if they only had 30 s to form that expectation. These results speak against lean proposals that passing the surprise-mark test does not indicate self-recognition (Heyes, 1994, 1998), and instead substantiate the view that, at least by 24 months of age, toddlers pass the test because they know what they look like (Amsterdam, 1972; Anderson, 1984a; Bertenthal & Fischer, 1978; Courage & Howe, 2002; Lewis & Brooks-Gunn, 1979; Nielsen et al., 2003). This does not mean, however, that passing the task need reflect a change in self-awareness, let alone theory of mind (e.g., Gallup, 1983). The current data do not speak for or against such rich interpretations. What is clear, though, is that the data do not support one set of intermediate proposals. Theories emphasizing changes specific to cognitions about one's face cannot explain the leg recognition performance we observed in our studies (e.g., theories that make a case based on the fact that one cannot otherwise directly observe one's face). We conclude that toddlers who pass the surprise-mark test can recognize features of their whole body, not just their face, and that when they pass the test they do so because they can form an updating representation of these features.

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