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The Development of Body Self-Awareness

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Two experiments examined toddlers' performance on a new task designed to examine the development of body self-awareness. The new task was conceived from observations by Piaget (1953/1977) and theoretical work from Povinelli and Cant (1995) and involved a toy shopping cart to the back of which a small mat had been attached. Children were asked to push the cart to their mothers but in attempting to do so they had to step on the mat and in consequence, their body weight prevented the cart from moving. In the first experiment, performance on the shopping cart task was examined in children of 16 and 21 months both when the self was the obstacle and when a heavy weight was the obstacle. Results showed significant improvement with age in performance for the self-version of the task that was not matched by similar age differences in the weight task. In the second experiment, children's performance on both the self-version of the shopping cart and on a standard mirror self-recognition task was assessed. Results showed a significant correlation independent of age for these 2 tasks. These findings provide further evidence for the notion that toddlers develop an objective awareness of the self during the 2nd year. They are also consistent with the idea that body self-awareness is heightened in situations requiring self-monitoring during movement.

For more than 100 years, psychologists have made a distinction between awareness of the first-person aspects of the self, what James (1890/1950) called the I, and awareness of the self as an object, the Me. It is generally accepted that some

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elements of first-person experience corresponding to the self are in place from early in the first year of life. For example, Bahrick and Watson (1985) demonstrated that infants from 3 to 5 months were able to detect the correspondence between visual and proprioceptive information of their own movements in the sense that they could extract an amodal temporal invariance when presented with live video of their own leg movements. There is also evidence that such young infants can also extract spatial invariances across visual and proprioceptive information (Rochat & Morgan, 1996).

In contrast to this early developing sensitivity to first-person information, the awareness of the self as an individual objective entity is generally believed to occur around the middle of the second year. For the last 30 years, the main approach to the study of objective self-awareness has been mirror self-recognition. This approach was first developed as a nonverbal method to study self-recognition in chimpanzees by Gallup (1970). Gallup anesthetized the chimpanzees and applied red dye to different parts of their bodies. When the animals recovered from the anesthetic, they were placed in front of a mirror. Gallup reported that under these conditions, chimpanzees would explore the red marks and in particular would use the mirror to explore marks on their faces. A similar procedure was used independently with young children by Amsterdam (1972), who used rouge to mark the cheeks of children from 3 to 24 months and then recorded their behavior in front of a mirror. Amsterdam reported that late in the first year and early in the second, children's most common response was to show a combination of social behavior to the mirror image, searching for the image in or behind the mirror, and observing the effects of their own movement in the mirror. Only after 18 months did children start to show evidence of recognizing the image as the self by touching the mark on their own faces.

This basic pattern using the marked face procedure has now been replicated many times (e.g., Bertenthal & Fischer, 1978; Johnson, 1982; Lewis & Brooks-Gunn, 1979; Nielsen, Dissanayake, & Kashima, 2003). It has also been extended to the recognition of a marked leg (Neilsen, Suddendorf, & Slaughter, 2006). Whereas the developmental pattern of behavior is quite well agreed on, there is still debate over what the behavior means. Some have argued that mirror self-recognition reveals little more than the learning of the reflective properties of mirrors and the use of mirrors to explore the body (e.g., Loveland, 1986). However, most authors agree that mirror self-recognition does tell us something interesting about the development of the self. In particular, it is generally believed that mirror self-recognition evidences children's representations of their appearance, whether more permanent as in facial appearance or relatively temporary, as in clothing (e.g., Neilson et al., 2006). In this way, facial appearance observed in the mirror is recognized by the child to be consistent with the child's mental image of himself or herself. Therefore, when the child sees the marked face in the mirror, the child immediately knows that the mark is on his or her own face.

Mirror self-recognition shows, then, that the child can imagine self from an objective point of view—as me.

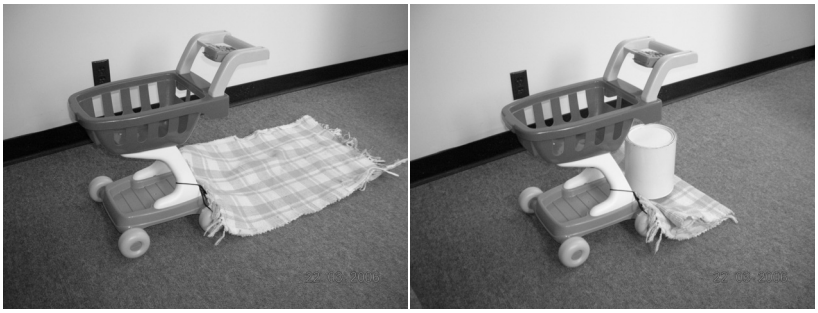
It has also been claimed that mirror self-recognition depends on the child's ability to process the identity relation between the visual information provided by the mirror and the proprioceptive information provided by the child's movements while in front of the mirror (Mitchell, 1993; Povinelli, 1995). It is important to note that processing the identity relation is more than just extracting the amodal temporal invariance for particular movements across proprioceptive and visual modalities, which, as we have mentioned, even very young infants can do (Bahrick & Watson, 1985). It means understanding that the two forms of information are equivalent (Mitchell, 1997; Povinelli, 1995). Given this equivalence, children can determine that what is true of the image in the mirror is also true of the self and therefore that the mark exists on their own face.

The mirror self-recognition task has been a productive research tool for a number of years; however, in that it is tied to the recognition of visual appearance, it is necessarily an assessment of only a limited aspect of the objective self. Clearly there are other aspects of the self and a greater variety of methods would be desirable if one wishes to assess the extent to which children acquire a general understanding of the objective nature of the self. One other construal of the self that is of interest to us here is the awareness of the self as a body with physical properties.

There is preliminary evidence that body awareness emerges at the end of infancy. Piaget (1953/1977) recorded the following observation of his daughter Jacqueline at 18.5 months: "Jacqueline is standing on a rag (50 × 30 cm.), which she is trying to pick up. She pulls, is surprised at the resistance, but it does not occur to her to move. Finally she gives up" (p. 351, obs. 168). Within a month she was able to solve such a problem. Piaget interpreted this observation and others (e.g., Piaget, 1954) in which his children attempted to negotiate the spatial environment and the causal relations among objects in that environment in terms of a developing awareness of self as an objective entity existing in, and interacting with, the world of objects. For Piaget, the objectification of the bodily self occurs as the infant becomes able to represent the body's spatial and causal relations with the external world (Piaget, 1954). Two studies have followed up Piaget's observations. Geppert and Küster (1983) and Bullock and Lütkenhaus (1990) sat toddlers on a small blanket and then asked the children either simply to give the blanket to the experimenter or to retrieve an attractive object hidden underneath the blanket. Most children were able to pass this task by 18 months. Although it is intriguing that children seem to be able to perform well on the blanket task at about the same time as they pass the mirror self-recognition task, it is unclear to what extent their success was the result of learning from similar situations that may have occurred regularly in natural circumstances. It is quite possible that infants have regularly found themselves sitting or standing on a blanket or cloth that they wish to retrieve.

In this study, we attempted to design a task involving novel circumstances that would test children's awareness of themselves as an objective entity with physical properties. In designing this task, we also wanted to provide a test under conditions in which the child was locomoting. There is a theoretical reason for believing that body awareness may be best elicited under conditions of locomotion. To understand why, it is necessary to consider how self-awareness may have evolved. There is strong evidence that mirror self-recognition is limited to the hominoid family. Whereas members of all great ape species have shown evidence of mirror self-recognition, monkeys do not (Povinelli, 1995). In the only existing explanation of why self-awareness evolved in the hominoid line, Povinelli and Cant (1995) argued that the particular ecological challenge of being a large-bodied primate in an arboreal environment resulted in an adaptation whereby the arboreal common ancestor of modern-day apes was able to construct an integrated representation of its body in relation to the environment. Based on their observations of arboreal locomotion of orangutans, Povinelli and Cant suggested that the particular challenge arose from the difficulty of moving a large and heavy body through an environment that was relatively unstable. The arboreal physical environment tends to be much more unpredictable in terms of support than the terrestrial physical environment. Under the weight of a large body, branches move and deform in unpredictable ways. They may break, leading to sudden loss of support. As a result, large-bodied arboreal apes cannot rely on stereotyped locomotion programs; rather, they need to constantly monitor the relation between all of their limbs and the environment to avoid the potentially severe negative fitness consequences of falling. In contrast, relatively small-bodied arboreal animals, including monkeys, are able to traverse their environment with relative impunity and so are able to rely on relatively stereotyped movement patterns in much the same way that humans do on flat surfaces once they have learned to walk or run. This is not the place to consider whether the overall paucity of relevant evidence from primate species warrants advancing an evolutionary account such as Povinelli and Cant's (1995) clambering hypothesis for the evolution of self-awareness (de Veer & van den Bos, 1998). Suffice to say that if they are correct, then one prediction is that self-awareness might be more likely to be elicited in situations involving a challenge to locomotion (see also Barth, Povinelli, & Cant, 2004).

Given this background, we designed a task that we believed would present such a challenge to locomotion. The task requires the child to push a toy shopping cart. Ordinarily, such a task would be straightforward for toddlers who are already walking without support. The difference is that our shopping cart is altered so that a small mat is attached to the back axle. The mat can be laid out to extend about 15 in. behind the handle of the cart (see Figure 1). If the child is to



(a) (b)

FIGURE 1 Toy shopping cart with (a) mat extended for self condition, and (b) paint can in place for object condition.

push the cart in the canonical manner, he or she must step onto the mat to grasp the handle. As a result, the child's weight impedes the forward motion of the cart. The child's pushing creates a force on the underside of the child's feet as the mat is pulled. The mat can also be folded so that it sits entirely under the handle, and in this arrangement, the child does not have to step onto the mat to push. At the same time, an independent weight can be placed on the folded mat to cause a similar impediment to forward motion.

In the first study reported here, we examined in a cross-sectional experiment whether there would be a difference in performance on the shopping cart task for children on either side of the 18-month transition. We predicted that older toddlers would show superior performance on the shopping cart task when compared to younger toddlers. Alone such a result would not be surprising—children improve on most measures of performance with age. Because our shopping cart task might be construed to require children to reason about the causal relations involved, a general development in causal (or mean–ends) reasoning might be responsible for performance improvements independently of any change in bodily self-awareness. To examine this issue we compared performance on self and object versions of the task. In the self-version, the child's own body acted as the impediment, whereas in the object version, a paint can filled with sand acted as the impediment.

In the second study, to further examine the idea that the shopping cart might tap into the development of awareness of self as an objective entity, we explored whether performance on the shopping cart task was related to performance on mirror self-recognition.

STUDY 1

Method

Participants

Eighteen 15-month-olds (8 girls and 10 boys) and twenty-one 21-month-olds (12 girls and 9 boys) from a small Canadian city participated in this study. All participants were within 1 month either side of their 15-month or 21-month birthday. Participants were recruited through birth announcements in local newspapers. All children were able to walk unassisted.

Material and Apparatus

The main apparatus used for this study was a child's plastic shopping cart (52 cm high to the handle). A pink-and-white checked mat was attached to the back of the shopping cart by means of string looped around the back legs of the shopping cart. The mat trailed behind the cart. Strips of Velcro were attached to the mat for ease of rolling up during the object trials. A 1-gallon paint can that had been painted white was used during the object trials. The paint can was full of sand and weighed about 5 kg. It was mounted on four furniture castors to allow greater ease of movement.

Procedure

On arrival at the lab, the participant was shown a variety of toys and was allowed to play with them to become familiarized with the lab setting and with the experimenter. After the experimenter and the parent judged that the participant was sufficiently accustomed to the lab setting and to the experimenter, the toys were put away and the experiment began. The whole session was videotaped for later coding.

Children in each age group were given both experimental tasks in a counterbalanced order. For purposes of simplicity, the self-task followed by the object task is presented here. After the toys had been put away, the experimenter approached the cart, which had been placed out of the participant's view, and placed the cart on a mark on the floor, with the mat laid out flat behind it. The experimenter then proceeded to demonstrate to the participant how to roll up the mat as well as how to push the cart. Following this, the experimenter allowed the participants to push the cart themselves with the mat rolled up so they would not step on it.

After familiarization with the cart and the mat, the cart was returned to the starting position, with the mat again trailing behind it. The parent was seated approximately 6 ft away. The experimenter placed the participant behind the cart and the mat. The experimenter then told the participant to "push the cart to mommy/daddy." The parent was also allowed to ask for the cart, but was

instructed not to give his or her child any information on how to complete the task. To reach the handle of the shopping cart, participants had to step onto the mat, thus preventing them from pushing the cart. Each trial continued until the participant successfully pushed the cart to his or her parent or the participant had walked away from the cart and did not display any further interest in the cart. The same procedure was repeated for a maximum of four separate trials, each one beginning with the participant being placed behind the cart and the mat.

For the object task, the mat was rolled up by the experimenter and fixed in place with Velcro, and the paint can was placed on the mat in place of the child's weight. At the beginning of each trial, the participant was placed directly behind the cart, and again asked to "push the cart to mommy/daddy." The parent was allowed to ask for the cart as well, as in the self-trials, and each trial continued until the participant successfully pushed the cart, or walked away and displayed no further interest in the cart. The same procedure was repeated for a maximum of four object trials.

Not all children completed all four trials of each task. For the self-task, 31 children completed all four possible trials, 4 completed three trials, and 2 children each completed only two and one trials. For the object task, 27 children completed all four trials, 9 completed three trials, and 3 completed two trials.

Coding and Measures

Primary coding was carried out by one coder who was otherwise uninvolved in the study and was naive to its purposes. She coded all participants on each completed trial for the following categories.

Successes. A success was scored if the child succeeded in moving the shopping cart at least one cart length toward the parent. This criterion was chosen because it meant the child had succeeded in moving the cart even if it was not pushed all the way to the mother. Success could not be achieved without stepping off the mat in the self-task or moving the paint can off the mat in the object task. In the self-task, success could be achieved by stepping to the side of the cart and pushing, moving to the front of the cart and pulling, or moving the mat out of the way and pushing. The most common strategy was to push or pull from the side or front. Only rarely was the mat moved out of the way. In the object task, success was typically achieved by pushing the paint can, which usually led to it tipping over and off the mat. Once the child had tried to move the paint can the experimenter would assist in moving it off the mat so that the child did not get hurt. When the paint can was off the mat, the cart could be pushed forward in the canonical manner. Each completed trial was scored dichotomously as either a success or not.

Attempts. An attempt was coded if the child placed both hands on the handle of the shopping cart and appeared to push. The form of attempts was the same for both self- and object tasks. All such attempts were counted for each trial so there could be more than one attempt per trial.

Reliability coding was carried out on 14 participants by a second coder also naive to the purposes of the experiment. For both successes and attempts reliability was good ($r = .88$ and .93, respectively).

Because not all children completed four trials for both self- and object tasks, measures of successes and attempts in both tasks were generated by dividing the successes and attempts raw scores by number of trials completed. For convenience, these two measures are referred to in what follows as successes and attempts. The success measure was a proportional measure with a possible range from 0 to 1. The attempts measure was the rate of attempts per trial completed. In addition, the raw attempts and successes measures were combined into a measure of overall performance efficiency across all trials of each task by dividing the total number of successes by the number of successes plus the number of attempts. The denominator here represents the total number of efforts the children had at pushing the cart, whether successful or not. Thus, this measure reflects in part the degree to which children engaged in trial and error. A high efficiency score reflects success with relatively few attempts and so may be more reflective of insightful problem solving. Thus for each task (self and object) there were three measures—successes, attempts, and efficiency.

Results

First, performance on each measure was compared to examine sex effects. Repeated measures analyses of variance (ANOVAs) with task as the within-subjects variable and age group and sex as between subject variables were run. The only significant sex effect was that boys ($M = .55$) had overall more successes than girls ($M = .36$), $F(1, 35) = 5.76$, $p < .05$, $\eta^2 = .141$. Attempts and efficiency did not show sex effects nor did sex interact significantly with age. Given that successes at least on the object task could be due in part to brute strength and that neither attempts nor efficiency differentiated boys and girls, sex was not considered further in the analyses.

Preliminary analysis was also conducted examining the number of trials of each task completed as a function of task order. This analysis showed a significant interaction of task and order, $F(1, 37) = 4.42$, $p < .05$, $\eta^2 = .107$). Children completed more self-trials than object trials when the self-task was first and more object trials than self-trials when the object task was first. Consequently, the two task orders were examined separately in all subsequent analyses.

For each order, the three main types of variables were analyzed with task (self, object) by age group repeated measures ANOVAs. The same analyses were also

TABLE 1
Means and Standard Deviations for Success, Attempts, and Efficiency on Each Task as a Function of Age Group and Task Order in Study 1

	Success				*Attempts*				*Efficiency*			
	Self		*Object*		*Self*		*Object*		*Self*		*Object*	
Task	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Self task first												
Younger	.342	.327	.308	.275	3.17	1.66	1.91	0.84	.099	.113	.113	.202
Older	.850	.269	.575	.409	2.30	1.23	3.23	1.77	.308	.166	.122	.181
Object task first												
Younger	.219	.364	.291	.388	1.89	0.85	2.33	0.99	.160	.203	.123	.170
Older	.349	.450	.636	.438	2.04	1.45	2.50	1.64	.152	.125	.256	.202

Note. Success was a proportion of number of trials completed that were solved and had a possible range from 0 to 1. Attempts was a rate measure. Efficiency was calculated according to the frequency of successes/successes + attempts.

carried out on raw frequencies of successes and attempts and the results did not differ. Means and standard deviations are shown in Table 1. When children received the self-task first, the analysis of successes showed a main effect of task, $F(1, 18) = 6.53$, $p < .05$, $\eta^2 = .266$, and a main effect of age, $F(1, 18) = 9.95$, $p < .01$, $\eta^2 = .356$. Children were more successful on the self-task than the object task in general and the older children were more successful than the younger children. The interaction was not significant, $F(1, 18) = 2.13$, *ns*, $\eta^2 = .106$. In contrast, when children received the object task first, there were no significant differences in success.

The analyses of attempts showed that when children received the self-task first, there were no main effects but a significant interaction between task and age, $F(1, 18) = 4.77$, $p < .05$, $\eta^2 = .209$. Younger children made more attempts than older children on the self-task but fewer attempts than older children on the object task. When the object task was first, there were no significant effects at all.

The analyses of efficiency revealed a significant interaction between task and age when the self-task came first, $F(1, 18) = 5.56$, $p < .05$, $\eta^2 = .236$. Older children were significantly more efficient than younger children on the self task ($t = 3.29$, $p < .01$, $d = 1.47$), but there was no significant difference between younger and older children on the object task. When the object task came first, there were no significant differences in efficiency.

Finally, correlations between the two tasks were run for each measure for each age group. None of these correlations were significant. In particular, for the self and object efficiency scores, the correlation was $r = .032$ for the younger group and $r = .140$ for the older group, indicating the relative independence of performance on the two types of task.

Discussion

This study was contrived to examine age differences in a task designed to tap bodily awareness. The self-version of the shopping cart task, conceived from ideas stemming both from Piaget's (1953/1977) observations and Povinelli and Cant's (1995) hypothesis of the origins of bodily self-awareness required children to locomote in a situation in which their own body would impede their success. The results showed that the older group of children, who were 21 months of age, were much more successful than the younger group, who were 16 months of age. This effect was seen most strongly for the condition where the self-version of the task was presented first. Performance was generally poorer when the self-task followed the object task, presumably because of fatigue and loss of interest. Indeed children completed fewer self-trials when this task was presented second and 2 of the children only completed one self-trial in this task order. Because of this order effect, it is important to pay most attention to performance when the self-task was presented first. Under these circumstances, the older children were successful at moving the cart forward on an average of 3.3 trials out of a maximum of 4, compared to the younger children who were successful on only 1.3 trials. At the same time the older children achieved this success with rather fewer attempts at pushing the cart. The combined efficiency measure shows that the success rate per try was much higher for the older group than for the younger group. This efficiency measure is the clearest evidence that the older children were much better able than the younger children to understand the demands of the task and solve it. It is perhaps worth mentioning, however, that not even the older children achieved efficiency anywhere close to 1. Thus, all children appeared to solve the task largely by trial and error. In short, there was no evidence of truly insightful problem solving in this task.

So far, this result is perhaps of little significance. After all, older children generally do better than younger children at most tasks. The older children had considerably more experience locomoting in general and so should be expected to perform better on tasks requiring locomotion. To determine whether the superior performance displayed by older children might be related to developing self-awareness, we also used a control task—the object task—formally equivalent to the self-task but not requiring any reflective self-awareness for success. Examination of performance on the object task when it was presented first showed no significant differences across age in success at moving the cart forward, attempts at moving the cart, or overall efficiency. These results suggest that the age-related performance seen on the self-task was not due to more general aspects of development, such as a change in general locomotory skill or in the ability to reason about the causal relations involved in the task. Rather it is something more specific to do with children's changing awareness of their own bodies in such circumstances. Although it is a null result, the finding that performance in

the self-task was not correlated with performance in the object task further supports the inference that the two tasks to some extent tap different abilities.

This relative independence of performance on the self- and object tasks might seem counterintuitive at one level. Certainly, according to a traditional Piagetian (1954) account, it might have been predicted that performance on the two tasks would be more closely related because both require cognitive abilities emerging at the end of the sensorimotor period. In particular, as children become able to consider the independent roles that objects can take up in spatial and causal relations, they should also become able to consider the self as one possible object in such relations. However, our results suggest that self-awareness is separate enough developmentally from more general aspects of spatial and causal reasoning to yield differentiable effects despite quite similar task demands.

Having shown that there were age-related differences in performance on the self-version of the shopping cart task, a second study was designed to explore further the idea that successful performance on this task taps into self-awareness. In this study, we examined children within the age range for their performance on both shopping cart performance and on a more standard measure of self-awareness—the mirror self-recognition task. The rationale was that if both tasks are valid measures of a developing awareness of the objective self then performance on the two tasks during the critical transitional age range should be correlated (see also Müller & Liebermann, 2004).

STUDY 2

Method

Participants

Twenty-nine children from the same population as in Study 1 participated in this study. Children ranged in age from 16 to 24 months (M = 18.27, SD = 2.36). Participants were primarily from White, middle-class families. One child from the original 29 was dropped from the experiment because she could not yet walk; one other child did not complete both tasks. For the final sample of 27, children ranged in age from 16 to 24 months (M = 18.32, SD = 2.39).

Procedures and Measures

On arrival in the laboratory, the participants were allowed to become familiar and comfortable with the setting. During this time the experimenter played with the child with some toys and the sessions began after the child was at ease. Children were given the shopping cart task first and the mirror self-recognition task second. Both tasks were videotaped for later coding.

Shopping cart task. The procedure for the shopping cart task was the same as in Study 1. For this experiment, the task ended when the child completed two successful pushes or completed four trials, whichever came first. The choice to end after two successes was made because there was some indication from our earlier work that children who were able to succeed immediately on the shopping cart task were less inclined to continue for four trials. A successful push was coded when a child pushed the shopping cart one full length of the cart. An attempt was coded when the child stood on the carpet and tried to push.

Mirror recognition task. The mirror self-recognition tasks followed a standard approach. After the shopping cart task was completed, a round sticker was placed on the child's forehead using the pretext of wiping some dirt from his or her forehead. The child was then placed in front of a mirror (65 cm high, 48 cm wide). No children attempted to remove the sticker before being placed in front of the mirror. After approximately 30 sec, if the child had not yet removed the sticker, the experimenter attempted to elicit self-exploration using the following series of prompts, leaving between each prompt an opportunity for the child to respond: "Who's that? What's that (the experimenter pointed to the sticker in the mirror)? Where is that sticker really?"

Measures. Coding of the shopping cart task was carried out in essentially the same way as for Study 1. Success scores were computed as proportions of trials completed. Attempts were computed as rates per trial. All coding was done by an individual who was blind to the purpose of the study. A second coder rated a random sample of 10 participants to assess interrater reliability. For both successes and attempts reliability was good (r = .86 and .95, respectively). For the mirror self-recognition task, the same coders examined whether and at what point the children reached up to their forehead. Reaching for the sticker before the prompts was coded as 2, children who reached up in response to the prompts were coded as 1, and children who did not reach up were coded as 0. This three-level coding was carried out to tap additional variability in performance on the grounds that some children in the age range studied might be transitional in mirror self-recognition and might only show it when explicitly prompted (or scaffolded) to do so. Interrater agreement for mirror self-recognition was perfect.

Finally, as for Study 1, an efficiency score reflecting both attempts and success was calculated (efficiency = successes /attempts + successes).

Results and Discussion

The mean scores for each measure were as follows: attempts, M = 1.33, SD = 1.27; successes, M = .47, SD = .38; efficiency, M = .30, SD = .28; mirror

TABLE 2
Correlation Matrix of Measures for Study 2

Variable	2[a]	3[b]	4[b]	5[b]
1. Age in months	.36*	.22	.43*	.26
2. Mirror score	—	–.10	.38*	.41*
3. Successes		—	.09	.79**
4. Attempts			—	–.43*
5. Efficiency				—

[a]$N = 28$. [b]$N = 27$.
*$p < .05$, **$p < .01$, one tailed.

self-recognition, M = 1.14, SD = .85. For the mirror self-recognition task, 8 children completely failed to touch the sticker, 8 touched the sticker only after the prompt, and 11 touched the sticker when first shown the mirror before the prompt. Performance on both self-tasks was consistent with previous research on children of around 18 months. There was considerable variability in performance on the shopping cart task and this was consistent with Study 1, which found that there was considerable improvement on this task between 16 and 21 months of age. This study also found variability in mirror self-recognition consistent with the well-replicated finding that children typically start to show self-directed behavior when they observe their own marked face in a mirror at about 18 months of age (e.g., Bertenthal & Fischer, 1978; Johnson, 1982; Lewis & Brooks-Gunn, 1979; Nielsen et al., 2003). So this study on children averaging 18 months yielded typical performance on two tasks assessing aspects of the objective self.

Bivariate correlations were performed for all variables including age. Given the clear-cut prediction made at the outset, a one-tailed test of significance was used and revealed that age correlated significantly with successes and mirror self-recognition but not with attempts and efficiency. Mirror self-recognition correlated significantly with efficiency (r = .411, $p < .05$) and successes (r = .375, $p < .05$). Table 2 presents the bivariate correlations.

Because significant correlations between two variables may be obtained through their common associations with more general underlying developmental factors, such as cognitive development, we next carried out correlational analyses between performance on the two tasks of self-awareness with age controlled. For all three shopping cart task measures (attempts, successes, and efficiency), partial correlations with the mirror self-recognition score were calculated, with age in months partialed out. Using a one-tailed test of significance, only efficiency was significantly correlated with mirror self-recognition (r = .35, $p < .05$). Inspection of the descriptive means in Table 3 indicates that children who scored 0 on the mirror self-recognition

TABLE 3
Means for the Three Shopping Cart Measures as a Function of Mirror Self-Recognition Score in Study 2

Mirror Self-Recognition Score	*Shopping Cart Success*	*Shopping Cart Attempt*	*Shopping Cart Efficiency*
0	.250	1.28	.154
1	.511	1.78	.376
2	.592	1.05	.496

Note. Success was a proportion of number of trials completed that were solved and had a possible range from 0 to 1. Attempts was a rate measure. Efficiency was calculated according to the frequency of successes/successes + attempts.

task had a lower efficiency score than children who scored 1 and 2. As well, children who scored 2 had a higher score than those who scored 0 or 1.

Table 3 also indicates an interesting pattern for the other two measures on the shopping cart task. Children who scored 0 on the mirror self-recognition task tended to have few attempts as well as few successes (*M* attempts = 1.28, *M* successes = .25). Children who scored 1 on the mirror self-recognition task made the most attempts and had more successes than those who scored 0 (*M* attempts = 1.78, *M* success = .51). Children who scored 2 on the mirror self-recognition task had the most successes, but also made the fewest attempts (*M* attempts = 1.05, *M* successes = .59). This pattern suggests that those children who were perhaps transitional on the mirror self-recognition task were able to solve the shopping cart task, but did so in a more trial-and-error fashion than the children who passed the self-recognition task without prompts.

Finally, as a more conservative test of the association between mirror self-recognition and shopping cart performance, we carried out univariate ANOVAs on the three measures of shopping cart performance—successes, attempts, and efficiency—with mirror self-recognition coded dichotomously as pass (touched the sticker either before or after the prompt) or fail (did not touch the sticker). Mirror self-recognition passers had more successes than failers, $F(1, 25) = 4.25$, $p = .05$, $\eta^2 = .15$, and passers were more efficient than failers, $F(1, 25) = 4.28$, $p = .049$, $\eta^2 = .15$. There was no difference between passers and failers in attempts to push the shopping cart.

The novel contribution of this study is simple. Performance on the two tasks used in this study was significantly correlated independently of age. In particular, performance on the mirror self-recognition task was significantly correlated with the shopping cart task efficiency measure, which represents how easily participants were able to solve the shopping cart task. It should be noted that, perhaps as a result of a relatively small sample size, the magnitude of the correlation was not

huge and was only significant using a one-tailed test. Nevertheless, this result implies that there is a developmental link between the two measures even though at face value they differ considerably. The link we suggest is that both evidence children's developing awareness of the objective status of the self. In the final section, we consider in more detail what this awareness entails.

GENERAL DISCUSSION

We have developed a new task of bodily self-awareness that reveals developmental change at about 18 months. This task requires children to be aware of themselves as objects that can interact physically with other objects in the world. The task presents children with a novel situation and so has the advantage that it is very unlikely that children will have acquired a solution method prior to testing. Younger children find the task difficult and when they do solve it, they appear to do so by trial and error. Older children solve the task more often and solve it with fewer attempts.

We believe that this task is a valid assessment of the understanding of self as an object. First, it is the objective physical nature of the actor's body that impedes forward motion on the shopping cart. Therefore, efficient solution of the task implies that the actor recognizes this characteristic. Second, we have convergent validity in the form of a significant age-independent correlation between performance on the shopping cart task and performance on the standard mirror self-recognition task. It is important to note that this correlation was moderate, implying that the two tasks tap related but different aspects of the objective self. Recently Brownell and colleagues (Brownell, Zerwas, & Ramani, 2006) also used a range of similar tasks with toddlers between 18 and 30 months and provided evidence for relatively dissociable aspects of the objective self. However, it is also noteworthy that the correlation between the two tasks in Study 2 was rather larger than that between the two versions of the shopping cart in Study 1, even though the latter two tasks present much more similar task demands and might be imagined to depend on a common understanding of causal relations.

Many authors have recognized the multifaceted nature of the self (e.g., James, 1890/1950; Lewis & Brooks-Gunn, 1979). Sensitivity to the first-person information specifying the self is clearly present early in infancy (e.g., Bahrick & Watson, 1985). However, the representation of the self from an objective or third-person point of view—the Me—develops later during the second year of life. But what counts as having an objective sense of self? On the one hand, representing self from an objective point of view entails understanding that the self is a unique object. The mirror self-recognition task reveals young children's awareness of the self as a particular entity—the self is a person who can be differentiated from other people based on visual appearance. On the other hand, representing the self

objectively entails recognizing that the self is also an object like other objects—it has physical properties that play a causal role in the world of objects. The shopping cart task assesses this aspect of the self.

If we are correct that the objective self comes to be understood both as a unique entity and also as an object like other objects, can we account for how these two facets of the objective self develop in close synchrony around the middle of the second year? Both of these facets require the child to imagine information about the self that is not typically available through direct perception (third-person information about the self) and then to relate it to information that is directly available through perception (first-person information, in particular via proprioception). Like other authors (e.g., Perner, 1991; Suddendorf & Whiten, 2001), we believe that more general developmental changes in representational ability play a role here. Around the middle of the second year, children become capable of holding in mind a secondary representation as they are engaged perceptually with the environment (primary representation). This capability is evidenced by a variety of cognitive and social achievements, including aspects of object representation, pretend play, and imitation (e.g., Lewis & Ramsey, 2004; Nielsen & Dissanayake, 2004; Suddendorf & Whiten, 2001). The capacity for secondary representation enables relations between perceived and imagined information to be established. The self as an entity with an objective nature is one conceptual outcome of this level of information processing.

Although recognizing the developmental role of the onset of secondary representation, it is also important to point out that the concept of the objective self requires the integration of the two sources of information about the self that appears to be facilitated under conditions of movement. Both Mitchell (1993) and Povinelli (1995) argued that mirror self-recognition depends on an awareness of the correspondence between the visual information of the self's movement in the mirror and the proprioceptive information provided from the same movement. Indeed if that correspondence is removed while maintaining visual information of the self's appearance by using delayed video, young children fail to show self-directed behavior (Povinelli, Landau, & Perilloux, 1996). Thus it is the monitoring of the contingent relation between the self's action and the visually apparent motion in the mirror that is essential for mirror self-recognition. The shopping cart task also presents children with a situation in which they must monitor the relation between their own movement and the movement (or lack of it) of the shopping cart that they are controlling. To solve the task, the children must recognize that their own body is the cause of the lack of effective movement. Arguably, then, this task also requires children to process and represent the contingent motion relations between self and world. The fact that even the older children in Study 1 solved the self-version of the shopping cart largely through trial and error rather than through insight is consistent with this idea. It is possible that this situation harkens back to the time when the earliest hominoid ancestors first were

confronted with the need to represent the movement of the objective self in relation to the environment (Povinelli & Cant, 1995).

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