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Brief Article

Five-month-old infants know humans are solid, like inanimate objects

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Abstract

Infants know that humans are exempt from some of the principles that govern the motion of inanimate objects: for instance, humans can be caused to move without being struck. In the current study, we report that infants nevertheless do apply some of the same principles to both humans and objects, where appropriate. Five-month-old infants expect humans, like all material objects, to be solid.

Keywords: Intuitive dualism; Core knowledge; Agency; Mentalising; Solidity; Cognitive development

1. Introduction

Very young infants expect inanimate objects to be solid (Baillargeon, Spelke & Wasserman 1985; Baillargeon, Needham, & DeVos 1992; Spelke, Breinlinger, Macomber & Jacobson, 1992) and cohesive (Spelke, Breinlinger, Jacobson & Phillips, 1993), to move along continuous paths (Spelke, Kestenbaum, Simons & Wein 1995), and to be caused to move (only) by contact (Leslie & Keeble, 1987; Oakes & Cohen, 1990; Kotovsky & Baillargeon 2000). Infants take humans, on the other hand, to be exempt from the requirement of contact causality (Spelke, Phillips & Woodward 1995; Kosugi & Fujita,

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2002), and infants instead interpret humans' behaviour in terms the pursuit of goals (Woodward, 1998). These early abilities have been characterised as reflecting 'core knowledge' of two fundamentally separate domains of cognition: naïve physics and naïve psychology (Carey & Spelke, 1994; Leslie, 1994; Fodor, 1983; Spelke, 2002).

Kuhlmeier, Bloom, and Wynn (2004) recently reported that while 5-month-old infants apply the principle of continuous motion to inanimate objects, they do not appear to apply the same principle to humans. Following continuous motion, infants expected a single object, and following discontinuous motion, they expected two objects (cf. Spelke, Kestenbaum et al., 1995; Spelke, Phillips et al., 1995). However, infants looked equally, when either one or two humans were revealed following either continuous or discontinuous motion. The authors conclude that in this paradigm infants 'mistakenly differentiate between [objects and humans], suggesting that at 5 months infants do not readily view humans as material objects.' Thus, Kuhlmeier et al. (2004) suggest that for young infants, categorisation as an intentional agent implies 'all bets are off' with respect to the principles that characterise core knowledge of naïve physics.

If Kuhlmeier et al.'s (2004) conjecture is corrent, then infants of this age should not apply the principle of solidity equally to humans and material objects. The principle of solidity—one solid object cannot occupy the same position as another solid object—is one of the earliest developing principles of infants' object knowledge (Hespos & Baillargeon, 2001). Indeed, the predicted suspension of the solidity constraint for humans provides a stronger test of the hypothesis that infants 'mistakenly' differentiate between objects and humans by not viewing humans as material objects. The discontinuous motion events used by Kuhlmeier et al. (2004) are actually consistent with infants' prior experience of the motion of humans, as opposed to inanimate objects. Humans often take devious paths between two points, go around obstacles, or go out one door and come in another. By contrast, infants have never seen a human apparently violate the principle of solidity.

2. Method

2.1. Participants

Thirty-four 5-month-old infants participated in the experiment (21 male, 13 female, mean age: 5;4, age range 4;12–5;25). Families were approached by letter from birth records and received a token gift for participation. An additional 14 infants were excluded because of fussiness. 18 infants were assigned to the train condition (mean age: 5;4) and 16 to the human condition (mean age: 5;3).

2.2. Procedure

Prior to the experiment infants were familiarised with two wooden walls: a long green wall (16 in. × 9 in. × 2 in.) and a short orange wall (6 in. × 9 in. × 2 in.). Each infant was shown each wall in turn, and encouraged to touch each one.

During the experiment, the infant sat on his/her parent's lap in a darkened experimental room, facing the brightly lit stage. The parent sat facing away from the stage, and was asked to keep his/her eyes averted from the stage throughout the experiment. The child's looking at the stage was recorded by a camera and fed to an on-line coding monitor in a different room; the coder was blind to the experimental condition. Twenty-five of the infants were coded simultaneously by a second coder. Average inter-coder agreement was 93%. Trial endings, determined by a 2-s look-away criterion, were signalled by a computer beep over a walky-talky, inaudible to the infant. A second camera recorded the events on the stage, so that the looking times could be recoded offline when necessary.

All events were created live on a black stage two feet in front of the infant (17 in. × 34 in.). The stage was hidden by an opaque black board, which could be raised to reveal the stage. A bright white strip (4.5 in. wide) was marked on the floor, creating a salient track across the whole width of the stage. At the front and centre of the stage was a small black 'occluder' panel (6 in. × 7 in.) that could be raised to block the infant's view of the central section of the track.

At the start of each habituation trial, the stage was opened and the leading edge of the test object (i.e. a live human hand in the 'human' condition, or the first carriage of a brightly coloured toy train in the 'train' condition) was visible at the left side of the stage. In the human condition, the hand was an open left hand, palm facing the baby, fingers together and thumb up.

The central 'occluder' panel was then raised, and the experimenter called out 'Look, [baby's name], look!' Once the panel was up, the test object moved smoothly along the white track, passing behind the occluder panel, and stopping when the leading edge of the test object had crossed 80% of the stage's width. No trailing edge of the test object was ever visible—both the human arm and the toy train extended out of the stage on the left side. Time spent looking at the stage on each trial was coded from the moment when the test object was first visible beyond the right edge of the central occluder, just before its motion was completed. Thus, most of the looking time reported here reflects infants' looking to an entirely stationary display.

Infants were presented with a minimum of 6 and a maximum of 12 habituation trials. Once infants had habituated (average looking time on the last three trials less than half of the average looking time on the first three trials) or once the maximum was met, the test trials began.

In the test trials, a wall was introduced into the centre of the stage. The short orange wall projected 2 in. into the stage, and its edge stopped before the visible white track. The long green wall, by contrast, extended 14 in. into the stage, clearly crossing the whole white track, and reaching right up to the central occluder.

On each test trial, the stage was opened with a wall in place. The central occluder was raised. Then, while the experimenter called out 'Look [baby's name] look: this one's different!', the central panel was lowered and the raised again. The motion of the occluder served to attract infants' attention to the centre of the stage to ensure that the infants had seen the wall. When the occluder was raised, the top 3 in. of the wall was visible above the top edge of the occluder, but the bottom of the wall was occluded. In a pilot study of 7 five-month-old, there was no initial preference for the long green (mean looking time = 3.2 s) or short orange wall (mean = 3.4 s) alone, in the absence of any test object (hand or train).

Once the occluder was raised for the second time, the trial proceeded just as in habituation: the test object rolled smoothly across the width of the stage, stopping at the same point. If an observer of this event is sensitive to the enduring existence and solidity of both the wall and the test object behind the occluder, the test trial involving the long green wall should attract attention, because this event appears to violate these expectations. The hand or train appears to pass right through the wall. The test trials involving the short orange wall do not include such a violation. The hand or train appears to pass in front of the wall.

Each infant saw four test trials, alternating between the green and orange walls. The wall presented first was counterbalanced across infants.

3. Results

In the train condition, 16 of 18 infants habituated in less than the maximum 12 trials. The mean number of habituation trials per infant was 8. The mean average-looking-time on the first three habituation trials was 14.6 s (SE 1.6), and on the last three habituation trials was 9.0 s (SE 1.4).

In the hand condition, 14 of 16 infants habituated; the mean number of habituation trials was 8.8. The mean average-looking-time on the first three habituation trials was 11.2 s (SE 2.5), and on the last three habituation trials was 5.7 s (SE 0.8). There was no significant difference between groups on any of these measures (all $P > 0.05$, independent samples *t*-tests).

An ANOVA with condition (hand versus train), test trial type (unexpected versus expected), and order (unexpected test trial first versus unexpected trial second) as factors, yielded a main effect of test trial type (Unexpected > Expected, $F(1,30) = 8.8$, $P < 0.01$), and no other main effects or interactions. Critically, there was no interaction between test trial type (expected versus unexpected) and the test object (hand versus train $F(1,30) = 0.02$, $P > 0.85$). The partial eta squared estimate of the effect size of this interaction was 0.001, suggesting that the interaction between test trial and test object accounted for less than one percent of the observed variance in infants' looking times. By contrast, the partial eta squared estimate of the main effect of trial type was 0.227 (23% of the variance) Fig. 1.

Planned analyses confirmed that infants in *each* condition were sensitive to the violation of sensitivity. Infants in the train condition looked longer at test events that included an apparent violation of solidity (mean 12.3 s, SE 1.9) than on test trials with no violation (mean 8.7 s, SE 1.6, $P < 0.03$ one-tailed, paired-samples *t*-test). 12 of 18 babies looked longer at the unexpected event; the preference for the unexpected event in individual babies was significant on a Wilcoxon signed-rank test ($P < 0.05$). On the unexpected trials overall, infants recovered from habituation, looking significantly longer than the average of their last three habituation trials ($P < 0.05$ one-tailed, paired-samples *t*-test). However, the infants generalized habituation to the expected test trials ($P > 0.4$, paired-samples *t*-test, Fig. 2(a)).

The same pattern was true of infants in the hand condition. The infants looked longer at unexpected (mean 11.7 s, SE 3.2) than expected test trials (mean 8.5 s, SE 2.0, $P < 0.03$ one-tailed, paired-samples *t*-test). 13 of 16 babies showed this pattern; the preference for the unexpected event in individual babies was significant on a Wilcoxon signed-rank test ($P < 0.05$). On the unexpected trials overall, infants recovered from habituation,

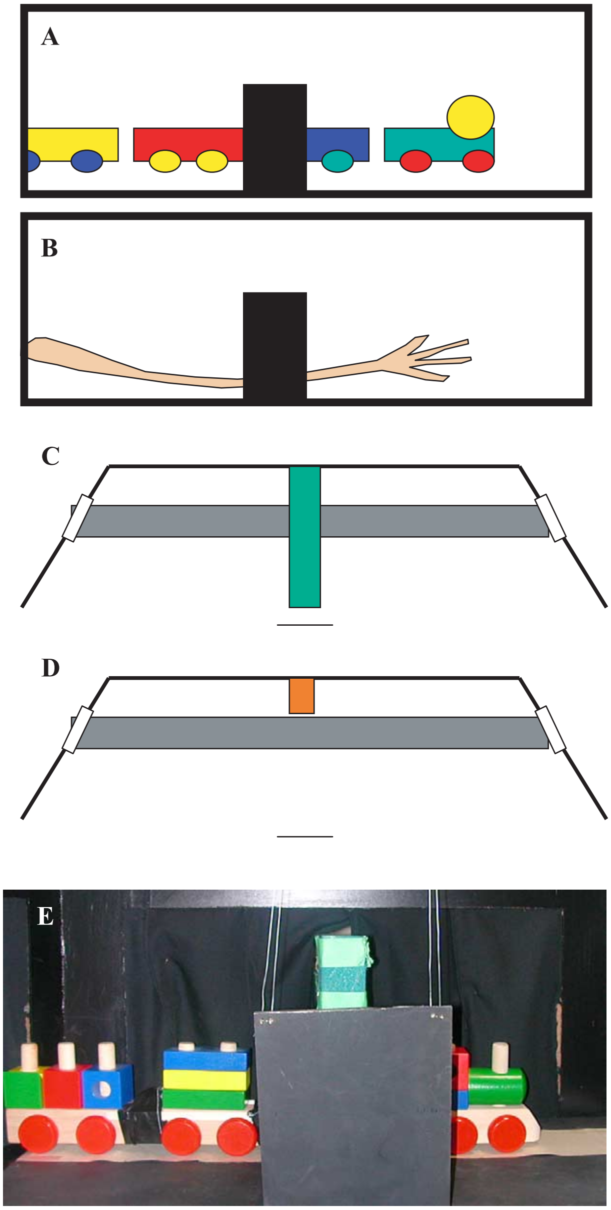

Fig. 1. Experimental set-up. (A) Schematic view of the end of a 'train' condition habituation trial, from the infant's perspective. The train extends across the stage from the left, and is partly occluded by the central panel. (B) Schematic view of the end of a 'human' condition habituation trial. (C) Schematic bird's-eye view of the stage with the long green wall in place. The wall crossed almost the entire depth of the stage, clearly blocking the track on the stage floor. (D) Schematic bird's-eye view of the stage with the short orange wall in place. (E) Photograph of the end of an unexpected (green wall) test trial, in the train condition.

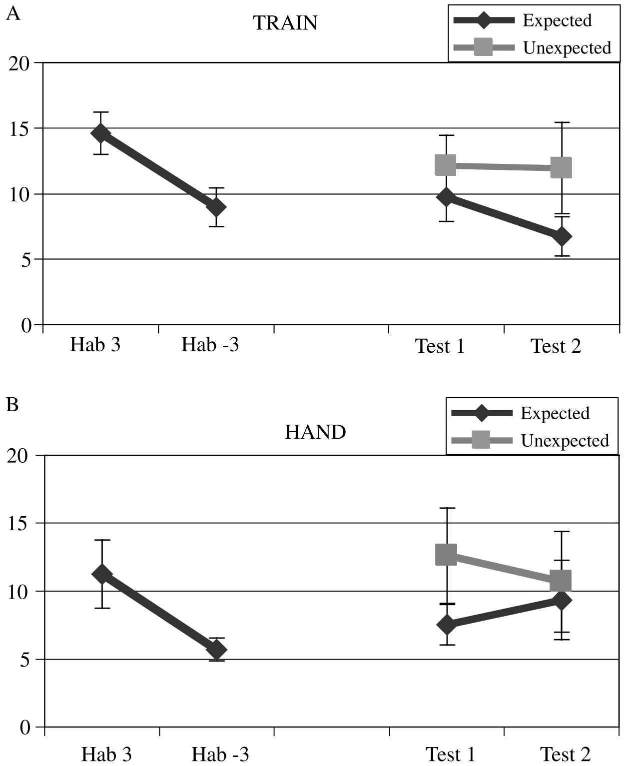

Fig. 2. Looking time results. (A) Train condition. $N=18$. Unexpected > Expected, $P<0.05$ one-tailed, paired-samples t-test. (B) Hand condition. $N=16$. Unexpected > Expected, $P<0.05$ one-tailed, paired-samples t-test.

looking significantly longer than on the last three habituation trials ($P<0.03$ one-tailed, paired-samples t-test). However, dis-habituation did not reach a one-tailed significance criterion in the unexpected trials ($P>0.05$ osne-tailed, paired-samples t-test, Fig. 2(b))[1].

4. Discussion

These data replicate the now robust finding that by five months old infants expect inanimate objects to be solid, and look longer when one inanimate object appears to pass through the space occupied by another. The new result is that at the same age, infants apply the solidity constraint equally to both inanimate objects (the toy train) and humans (the

[1] One reviewer requested 95% confidence intervals for the main effect of trial type (Unexpected vs. Expected trials) and for the interaction between condition (Hand vs Train) and trial type. These are: for the main effect of trial type: mean 3.4, 95% interval 1.15–5.65 s, and the interaction of trial type with condition: mean 0.38, 95% interval −4.20:4.96 s. The large confidence intervals are the result of typically high variance in young infants' looking times.

human hand and arm). Thus, while infants differentiate between humans and material objects in appropriate ways (Spelke, Phillips et al., 1995; Kosugi & Fujita, 2002, Rakison & Poulin-Dubois 2001), infants also sometimes apply the same physical laws when reasoning about the motion of humans and inanimate objects.

What accounts for the difference between the current results, and those of Kuhlmeier et al. (2004) who report that 5-month old infants do not apply the continuity constraint to humans as they do to inanimate objects? One possible resolution is to take both results at face value, and conclude that infants expect humans to be solid but not necessarily to be restricted to move on continuous paths through space. However, this resolution seems unpromising. The constraints of solidity and continuity are conceptually closely related. If an entity moves on a spatially continuous path, it cannot dematerialise on side of a barrier and re-materialise on the other side. Conversely, if infants truly suspended the continuity constraint for humans, then they might have seen the human hand motion in the 'unexpected' test trials of the current study as merely discontinuous.

A second possibility is therefore that infants do not suspend the continuity constraint for humans (i.e. expect that humans cannot de-materialise and re-materialise), but rather simply allow humans to take unseen circuitous routes from one point to another. In the experience of the infant, humans frequently reappear in positions quite different from where they were last seen. The current study design did not allow infants to suppose that the hand had 'gone around' the wall, and so forced them to perceive a violation of solidity.

A third possible account of the discrepancy concerns the entities involved in the impossible events in the two studies. For their 'human' condition, Kuhlmeier et al., (2004) used a video of a whole human body walking, while the current study used only a part of a human body—a hand and arm. It might therefore be objected that for infants whole humans fall within the domain of naïve psychology, but parts of humans do not. However, most of the evidence that infants interpret the actions of humans as goal directed, and differentiate humans from inanimate objects in this regard, is from paradigms using only human hands and arms as stimuli (e.g. Woodward, 1998).

Upon further reflection, it seems that the core knowledge hypothesis is not only consistent with the current observation that infants expect humans to be solid, but even predicts it. On most characterisations of core knowledge (Carey & Spelke, 1994; Leslie, 1994; Fodor, 1983; Spelke, 2002), the entities within each domain are automatically identified by dedicated, modular input analysers, operating in parallel. If so, then a single coherently moving whole could be simultaneously identified as a face, as an intentional agent, and as a material object, by input analysers responding to different features of the same entity. Categorisation as an agent or as an inanimate object would only be mutually exclusive if there were inhibitory connections between these systems. The challenge for infants (and adults) may not be in perceiving that humans are simultaneously intentional agents and material objects (Bloom, 2004), but in seeking to understand *how* they can be so.

In any case, the strong claim that young infants have entirely distinct modes of construal for inanimate objects and humans (Kuhlmeier et al., 2004; Bloom, 2004) must be qualified. Five-month-old appear to understand that at least with respect to solidity, humans are just like inanimate objects.

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