Original Articles

Infants' agent individuation: It's what's on the insides that counts

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ABSTRACT

Adults and preschool-aged children believe that internal properties are more important than external properties when determining an agent's identity over time. The current study examined the developmental origins of this understanding using a manual-search individuation task with 13-month-old infants. Subjects observed semi-transparent objects that looked and behaved like animate agents placed into box that they could reach but not see into. Across trials infants observed objects with either the same- or different-colored insides placed into the box. We found that infants used internal property differences more than external property differences to determine how many agents were involved in the event. A second experiment confirmed that this effect was specific to the domain of animate entities. These results suggest that infants are biased to see an agent's 'insides' as more important for determining its identity over time than its outside properties.

1. Introduction

The way we reason about other people is fundamentally biased towards properties that lie beneath the surface. When making basic decisions about who someone is and how they are likely to behave we often ignore salient surface properties in favor of more internal and unobservable features. For example, adults judge whether a person is the same individual over time based on psychological properties like memory (Blok, Newman, & Rips, 2005; Rips, 2011), and represent that people from the same social group share similar beliefs even though they differ in their external appearance and behaviors (Hirschfeld, 1996). This bias sometimes manifests itself as a biological attribution where an agent's 'insides' are seen as being a greater determinant of its identity than whatever surface properties it may exhibit (Medin & Ortony, 1989; Newman & Keil, 2008; Taborda-Osorio & Cheries, 2017).

Young children's explicit judgments reveal an early understanding that internal properties are more relevant than external properties when reasoning about agent identity. For example, 4-year-olds infer that animals belonging to the same category are more likely to share more internal, non-observable properties than external and observable ones (Gelman & Markman, 1986). When internal and external properties are pitted against each other in a categorization judgment task 5-year-olds reliably use internal physical properties such as blood or bones to categorize animals but not artifacts (Diesendruck, 2001; Diesendruck, Gelman, & Lebowitz, 1998; Diesendruck & Peretz, 2013). Furthermore, 7-year-old children who observe salient changes to an animal's external appearance insist that the animal's categorical

identity remains unchanged, such that a tiger with its stripes erased is still a tiger (Keil, 1989). On the other hand, when preschool-aged children are told that the *insides* of an animal are removed or changed they infer that their categorical identity should change as well (Gelman & Wellman, 1991). The same pattern of results has been found when children evaluate the individual identity of an animal across transformations by using internal psychological properties (Gutheil & Rosengren, 1996). For instance, children as young as 4 years of age know that an animal's food and behavioral preferences (e.g. a dog liking to chew bones) remain stable regardless of salient surface transformations.

Since children seem to apply these beliefs to living things and not to simple artifacts (Gelman & Wellman, 1991) some researchers have proposed that this type of reasoning reveals biological essentialist beliefs in children (Ahn et al., 2001; Gelman, 2003; Hall, 1998; Meunier & Cordier, 2009). From this perspective, natural kind objects, but not artifacts, are represented as possessing an underlying reality which is causally responsible for the pattern of observable features (Gelman, 2004; Medin & Ortony, 1989). As a consequence, non-visible properties such as an agent's insides are regarded as more relevant and diagnostic of identity than any external properties.

When over development does this sensitivity to internal features in biological functioning emerge? Some evidence indicates that direct experience with the biological world and explicit instruction about biology may mediate changes in the way children represent the causal role of animals' internal properties (Rhodes & Gelman, 2009). However, more recent studies suggest that an early form of this understanding

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could also emerge from more elemental cognitive biases that allow infants to represent animals' intrinsic properties and prioritize them over their external properties under some circumstances. For example, by 8 months of age, infants expect that an object that looks and acts alive should possess some physical internal properties (Setoh, Wu, Baillargeon, & Gelman, 2013). In this study infants who were shown objects displaying both self-propelled movement and agentive cues (e.g. being all covered with fur), looked longer when the biological agents appeared to be hollow rather than full on their insides. This suggests that infants may represent internal features as a biological property that is unique to entities that look and behave like animals. This pattern of results is consistent with an early developing "innards" principle (Gelman, 1990), the belief that something inside the animal is causally responsible for self-propelled movement (internal energy) and agency (internal states).

Beyond the general expectation that self-propelled agents have insides, infants have also been shown to make more specific inferences in the reverse direction—first observing an agent's internal properties and then using those features to create novel categories or to infer various behavioral properties. For example, 14-month-old infants will treat novel animate objects as if they belong to the same category when they share similar insides, while inanimate objects are categorized based on their external appearance (Welder & Graham, 2006). At this same age infants will also automatically associate an agent's idiosyncratic movement to the color of an internal part rather than to a salient external feature and generalize this association to other animate objects with the Different Outsides, despite their 'outsides' being perceptually distinct (Newman, Herrmann, Wynn, and Keil (2008). Furthermore, infants only seem to prioritize internal features when the objects in such tasks exhibit self-propelled behavior; when objects were moved by external means infants did not show a bias toward internal features (Newman et al., 2008).

Overall, the developmental research described above suggests that infants represent an agent's internal properties as more relevant than its external features when forming new categories or generalizing properties across individuals. Additionally, some of this evidence suggests that the internal features may be represented as a biological property, presumably with causal potency (e.g., Setoh et al., 2013). However, these prior results leave open an important question regarding how internal properties relate to infants' representations of agents—do infants represent an agent's 'insides' as more strongly connected to its individual *identity* than its external properties? In previous tasks, infants may have associated an internal feature with a particular movement type without necessarily treating an agent's insides as a powerful cue that determines whether they are the *same* agent over time. If infants represent insides as a biological property, then they may regard them as more diagnostic than external, non-biological, properties in an identity judgment. In this way 'insides' would not be represented merely as a distinctive property of animate entities, but also as an essential feature that helps distinguish both the individual and categorical identity of agents through changes over time.

The question of how infants represent the identity of objects over time has been most commonly addressed in the developmental literature through so-called individuation experiments. In the classic version of these experiments infants witness various objects move in and out of view from behind an opaque barrier. Afterwards, the screen is lifted to reveal the number or objects involved in the event and infants' looking-time responses are recorded. Experimenters estimate the number of objects that were represented based upon observing how long infants look at displays containing either 1 or 2 objects (for example see Xu & Carey, 1996). Since infants might only see one object appear from the barrier at a time, experimenters can determine which features (color, shape, texture, etc.) infants use to represent the objects as separate individuals. Some of these individuation experiments have demonstrated that infants sometimes disregard superficial perceptual features and use abstract conceptual information to individuate objects (Kingo &

Krojgaard, 2011; Xu & Carey, 1996; Xu, Carey, & Quint, 2004; Xu, Carey, & Welch, 1999). For example, 10-month-old infants represent two objects behind a screen when one object displays a self-propelled movement while the other one's motion appears externally-caused (Surian & Caldi, 2010). By contrast, infants fail to represent two objects behind the screen when two agents with different superficial features are presented. This pattern of results suggests that infants are able to use the abstract ontological distinction between "agent" and "inert object" to represent object identity.

These prior individuation studies demonstrate that from very early on infants represent some non-obvious properties (e.g., self-propelled motion) as more important than surface features when representing object identity. One intriguing possibility is that infants attribute such non-obvious properties to an agent's physical 'insides' as an initial placeholder for what determines an agent's appearance, behavior, preferences, and most basically, its identity as an individual. However, no prior experiment has determined whether infants spontaneously use biologically based cues such as an agent's 'insides' to establish representations of new individuals. The purpose of the current experiment was to examine this possibility by using a manual-search version of the classic individuation task (Feigenson & Carey, 2003; Van de Walle, Carey, & Prevor, 2000). In this paradigm infants observe one or more objects being placed inside an opaque box, which they can reach but not see into. The number of individual objects the infant represents is then estimated by observing the duration of their subsequent reaches into the box (e.g., a representation of two objects inside the box will lead infants to engage in a longer search duration than a representation of one object). In order to determine whether infants are sensitive to an agent's 'insides', we systematically manipulated whether changing the internal or external features of transparent objects hidden in a box would affect their individuation judgments. In order to test whether a sensitivity to internal properties was specific to agents, we manipulated whether the stimuli did or did not display agent-like cues (i.e., possessing eyes and exhibiting self-propelled movement; similar to those used in Newman et al., 2008). We tested infants who are approximately 13 months, an age that aligns with prior individuation demonstrations using this task (e.g., Feigenson & Carey, 2003) and demonstrations of infants' sensitivity to internal properties (Newman et al., 2008).

Experiment 1 was designed to test two hypotheses: first, that infants will represent differences in an agent's *internal* properties as highly diagnostic of a change to the agents' identity even when external properties remain the same; and second, that infants will represent differences in an agent's *external* properties as less diagnostic of a change to the agent's identity when internal properties remain the same. Experiment 2 was designed to test the hypothesis that the connection between an individual's 'insides' and its identity should be stronger for agents than for inanimate objects. Experiment 3 replicates the results of Experiment 1 and controls for possible stimulus-based effects.

2. Experiment 1

2.1. Method

2.1.1. Participants

Sixteen 13-month-old infants participated in this experiment (mean age = 13 months and 12 days, SD = 8 days). Half of the infants were girls. All infants were recruited from the Amherst, Massachusetts area. An additional 6 infants were tested but were excluded because of fussiness (2), experimental error (1), and disinterest (3). Fussiness was operationalized as instances where infants showed irritation along the experiment, for example, by crying or hitting the materials on the table. Disinterest was operationalized as instances where infants did not focused their attention on the task and did not try to reach into the box.
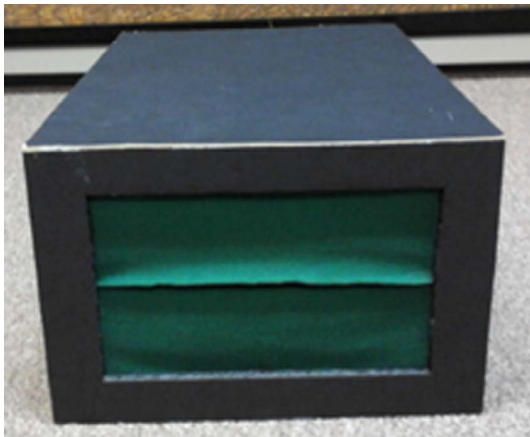
Fig. 1. Box.

2.1.2. Stimuli

Infants observed six transparent toys being hidden in a black foam-core box (see Fig. 1). The box measured 25.5 cm wide × 32.5 cm deep × 15 cm high. Its front face had an 18.5 × 10 cm opening covered by green spandex material, with a horizontal slit. The back face of the box had a 21 × 11 cm opening covered by a black spandex material. All six toys were transparent plastic spheres (5 cm in diameter) that were covered on the very top and on the bottom with acrylic paint (see Fig. 2 for examples). Inside each sphere there was a small cube made of foam painted with a color that is clearly visible from the outside. A total of 6

toys with different color combinations were used. Toys in the Different Outsides Condition contained inner cubes of the same color whereas paint on the sphere's surface was a different color. Toys in the Different Insides Condition contained inner cubes with contrasting paint colors whereas paint on the spheres' surfaces were identical (see Fig. 2). All toys were stabilized by a metallic washer attached to the bottom, and had two googly eyes glued on the front surface. A small magnet was attached in the center of the washer so that the experimenter could move the toy from below the top surface panel from inside the box with another small magnet. From a front perspective, the total visible surface area that was covered with paint on the outside matched the total visible surface area of the inside cube.

2.1.3. Design

All subjects received two Trial Types 1-Object and 2-Object trials. In the 2-Object trials, toys had either insides with the same color ('Different Outsides') or insides with different colors ('Different Insides'). Subjects received two blocks (Different Outsides Condition and Different Insides Condition) of four trials each (two 1-Object and two 2-Object trials). Within each comparison block, the number of objects was presented in two different orders; either 2-1-1-2 or 1-2-2-1. Both Block Order, whether infants received either Different Outsides or Different Insides first, and Trial Order, whether infants receive either 1-Object or 2-Object trial first, were counterbalanced across participants.

2.1.4. Procedure

Infant subjects were seated on their parent's lap in front of a table. The experimenter was seated in a chair on the side of the table adjacent
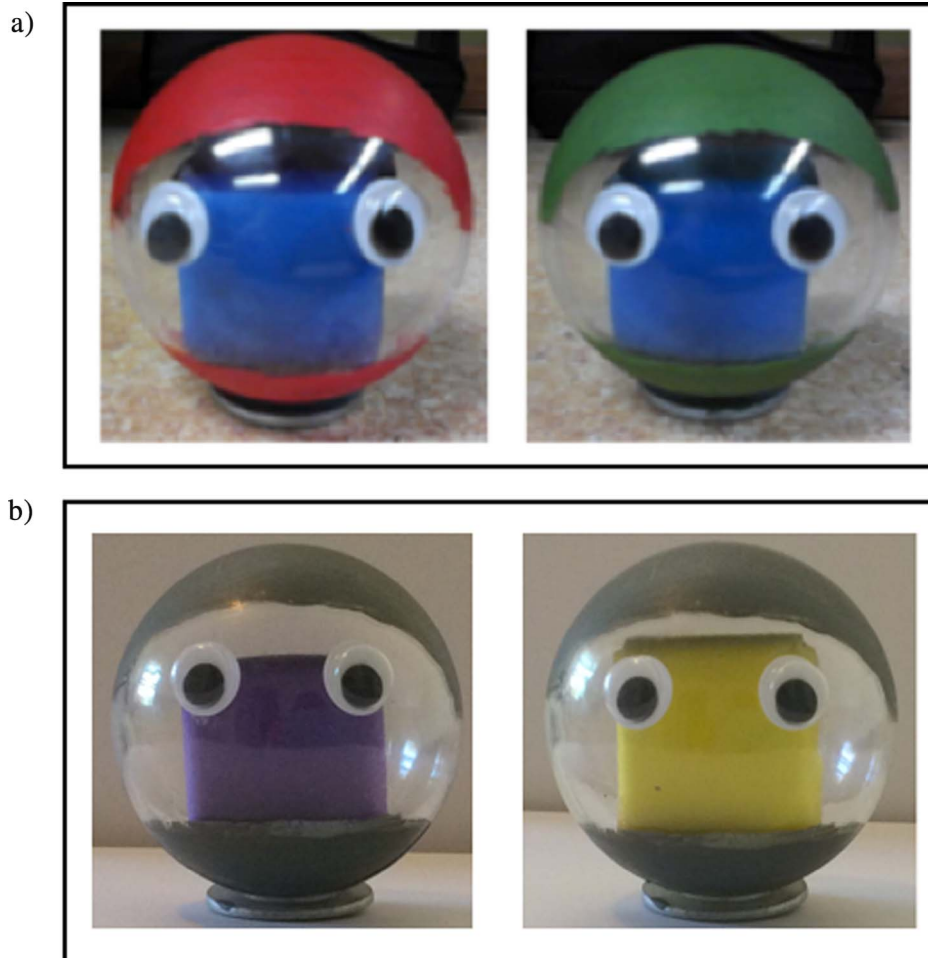

Fig. 2. Examples of the animate objects used in the (a) Different Outsides Condition and (b) Different Insides Condition of Experiment 1.

to the child. A camera recorded a side-view of the session. The procedure was composed of both a familiarization and test phase.

2.1.4.1. Familiarization phase.
The experiment began with two familiarization trials. First, the experimenter brought out a box and showed it to the infant. He reached into the box and encouraged infant to do the same. Next, the experimenter brought out a toy duck, and then he inserted the toy through the opening of the box. Infants were encouraged to reach in and retrieve the toy. This procedure was then repeated with a different toy. Once infants appeared to be comfortable reaching inside the box the experimenter moved on to the test phase.

2.1.4.2. Test phase.
1-Object trials measured infants' searching within the box after retrieving the one object they saw hidden ('Box Empty' trials). First, the experimenter brought out a transparent toy from the box, which was placed out of reach. The toy was then placed on top of the box where it immediately began moving in an animate fashion across the top surface for about 6 s. The object's movement was surreptitiously controlled by the experimenter from inside the box using a magnet and the toys followed motion paths with sharp and sudden changes in speed and direction that are known to elicit strong impressions of intentional agents (Tremoulet & Feldman, 2000). After the toy had stopped moving the experimenter grabbed the toy and inserted it through the box's front opening. The experimenter then slid the box forward so that it was within reaching distance of the infant and assumed a neutral expression looking down towards the ground. The infants were then allowed to reach into the box and retrieve the toy. Once this happened he/she was allowed to play with the toy for about 5 s before the experimenter took it away and placed it under the table and out of view of the subject. Once the experimenter finished stowing-away the toy a 10-s coding window began. During this coding window the experimenter looked down to avoid any interference and the infant was allowed to reach into the box. After the 10 s elapsed, the experimenter removed the box and the trial ended.

The 2-Object trials had the same structure as 1-Object (Box Empty) trials but it contained two separate coding periods: one 10-s coding period after both objects had entered the box but only one had been removed by the infant (a "1 Remains" trial), and a second after both objects had been retrieved (a "Box Empty" trial). Two-object trials began in the same fashion as the 1-Object trials, with the experimenter placing the box on the table out of the infant's reach and bringing out a toy from the box that then moved along the surface in a self-propelled manner. After putting the toy into the box, the experimenter brought out a second toy and repeated the same procedure. As the experimenter inserted this second object back into the box, he surreptitiously held it at the back entrance of the box so that it was hidden from the infants' grasp. Infants were then allowed to recover the one available object from the box. After allowing the infant a few seconds to play with the toy they retrieved, the experimenter took the toy from the infant and started the first 10-s coding period (a "1 Remains" trial) by looking down toward the ground in order to not bias the subject's responses. After 10 s, the experimenter retrieved the second toy that was hidden at the back of the box and handed it to the infant. After allowing the infant a couple of seconds to play with the toy, the experimenter took the toy away and started the second 10-s coding period (a 'Box Empty' trial). At the end of this coding period the experimenter retrieved the box and began the next trial. Since these 2-object "box empty" trials occur last within the longer trial sequence, infants' reaching is typically lower relative to the other coding periods (due to decreased interest in the task over the course of the sequence). For this reason, previous work using this method sometimes avoids analyzing data from these trials separately (e.g., Feigenson & Carey, 2005; Feigenson & Halberda, 2004). Although we report the data from these trials, because any relative difference with such 2-object box empty trials is difficult to interpret, the most critical comparison using the method is between 1-object box empty and 2-object 1-remains trials.

2.1.5. Data scoring
The dependent measure was the duration of each reach that occurred within each 10-s coding window. A reach was defined as any movement that results in the third knuckles of the infant's hand disappearing in the box. The duration was coded by two independent observers who were blind to the conditions. The inter-observer agreement was high (r = 0.94).

2.2. Results and discussion

Preliminary analyses found no effects of Sex or Block Order. We did find a significant effect of Test Order ($F(1, 8) = 8.6$, p = .02), due to longer searching for infants who had trials ordered 1,2,2,1 versus 2,1,1,2. However, there was no interaction between this variable and any within-subjects variables; therefore, all three between-subjects effects were collapsed in subsequent analyses.

A 2 (Condition: Different Outsides vs. Different Insides) × 3 (Trial Type: 1-Object Box Empty, 2-Objects 1 Remain, 2-Objects Box Empty) analysis of variance (ANOVA) revealed a significant main effect of Condition, $F(1, 30) = 5.63$, p = .031, $\eta^2p = .27$, which resulted from longer search times in the Different Insides condition (M = 2.7, SD = 1.87) than in the Different Outsides condition (M = 1.75, SD = 1.3). The main effect of Trial Type was also significant, $F(2, 30) = 8.05$, p = .002, $\eta^2p = .35$, due to infants searching longer on 1 Remain trials (M = 3.1 s, SD = 2.4) than on 1-Object Box Empty (M = 2.1 s, SD = 1.93) and 2-Objects Box Empty (M = 1.49 s, SD = 1.58; see Fig. 3). Finally, there was a Condition X Trial Type interaction, $F(2, 30) = 4.64$, p = .017, $\eta^2p = .23$, that was followed-up with planned comparisons t-tests (Bonferroni corrected). In the Different Insides condition, the comparisons between 2-Objects 1 Remain and both "box empty" trials were statistically significant, $t(15) = -3.3$, p = .01, d = 0.86, two-tailed, for 1-Object Box Empty, and $t(15) = 4.34$, p = .002, d = 1.15, two-tailed, for 2-Objects Box Empty, due to infants searching longer on 1-Remain trials (M = 4.03 s, SD = 2.69) than in 1-Object Box Empty (M = 2.4 s, SD = 2.08) and 2-Objects Box Empty trials (M = 1.69 s, SD = 1.84). In the Different Outsides Condition, the comparison between 2-Objects 1 Remain and 1-Object Box Empty was non-significant, $t(15) = -0.68$, p = .75, d = 0.17, two-tailed, (M = 2.16 s, SD = 1.77, and M = 1.8 s, SD = 1.77, respectively) while the comparison between 2-Objects 1 Remain and 2-objects Box Empty (M = 1.28 s, SD = 1.29) was statistically significant, $t(15) = 2.61$, p = .04, d = 0.7, two-tailed. Finally, the comparison between 1 Remain trials across conditions revealed a significant difference, $t(15) = -3.48$, p = .003, d = 0.94, two-tailed, due to infants searching
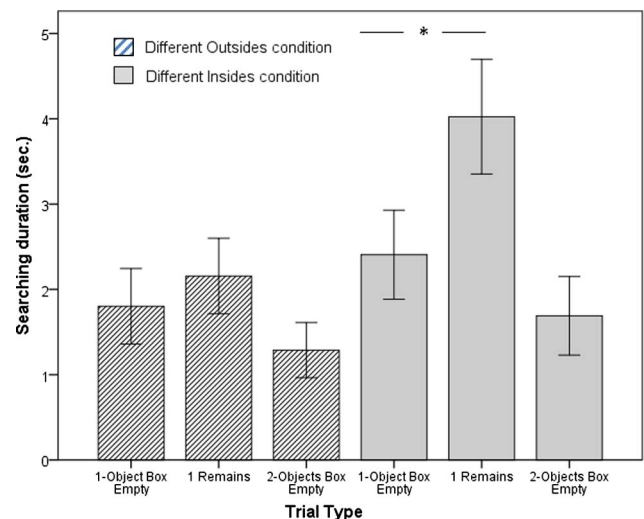

Fig. 3. Searching duration of Experiment 1. Error bars represent standard error of the mean. Asterisks mark statistically significant differences (p < .01).

longer on Different Insides trials than in Different Outsides trials.

A non-parametric Wilcoxon test confirmed the pattern of results obtained with the planned *t*-test. In the Different Insides condition, the differences between 1 Remain and both "box empty" trials were significant (Z = −2.58, p < .01, for 1-Object Box Empty, and Z = −3.36, p < .01, for 2-Objects Box Empty). In the Different Outsides condition, the difference between 1 Remain and 2-Objects Box Empty was significant (Z = 2.06, p = .02). However, the difference between 1 Remain and 1-Object Box Empty was non-significant (Z = −0.97, p = .17). The difference between 1 Remain trials across conditions revealed a significant difference (Z = −3.02, p < .01). Finally, the number of infants who searched longer during 1 Remains trials than in 1 Object Box Empty trials was significant in the Different Insides condition, (n = 12 out of 16; p = .037, 1-tailed binomial test), but not significant in the Different Outsides condition (n = 9 out of 16; p = .4, 1-tailed binomial test). The number of infants who searched longer in the Different Insides condition than in the Different Outsides condition in 1 Remain trials was significant (n = 14 out of 16; p = .002, 1-tailed binomial test).

The results from Experiment 1 provide evidence that infants spontaneously use internal properties differences between agents to represent numerically distinct individuals over time. In support of our first hypothesis, when infants observe two agents with Different Insides but identical outsides, they have a strong impression of two different individuals participating in the event. By contrast, and in support of the second hypothesis, when infants observe two agents with identical insides but different outsides their impression of two different individuals is statistically the same as the impression of one individual in the 1-Object Box Empty trial. This pattern of results indicates that infants represent insides as more diagnostic of an agent's identity than its external properties. Of course, infants might also encode the difference between the external appearances of the two agents but this difference may not be represented in a way that is meaningful enough to represent the agents as separate individuals.

One possible explanation for why infants would privilege an agent's internal properties for the purpose of individuation is that they possess an implicit understanding that an agent's 'insides' are more causally central to an agent's identity than its outside features. On this view, infants may show less regard for external property differences when there are clear indicators of internal properties—properties that carry more biological and causal significance—that remain the same. Alternatively, the differences in infants' performance between Different Outsides and Different Insides conditions could also be the result of lower level strategies. In particular, infants might use internal properties to individuate agents because they are in a central position and they possess a 3D structure, while the external properties are on the periphery and (in our study) only exhibit a 2D appearance. If this were the case, then we should observe that infants will use internal properties to keep track of an object's identity independent of that object's ontological status (i.e., a living thing vs. an inanimate object). In order to test these alternative explanations Experiment 2 replicated the same basic procedure except using inanimate objects that lacked eyes and self-propelled movement.

3. Experiment 2

3.1. Participants

Sixteen 13-month-old infants participated in this experiment (mean age = 13 months and 11 days, SD = 8 days). Half of the infants were girls. All infants were recruited from the Amherst, Massachusetts area. An additional 8 infants were tested but were excluded because of fussiness (1), or disinterest (7). Fussiness and disinterest were operationalized as before.

Fig. 4. An example of the stimuli used in Experiment 2.

3.2. Stimuli, design, procedure

The stimuli, design, and procedure for the second experiment were the same for that of Experiment 1, except that both animacy cues (i.e., eyes and self-propelled movement) were eliminated. The toy's eyes were replaced by two white circles in order to maintain the same balance between the visible covered area of the cube inside and the outside. However, these white circles were attached in a vertical configuration to avoid any resemblance to a face (see Fig. 4). To eliminate the self-propelled motion cue each toy was visibly moved by the experimenter's hand, following an identical motion path that the toys traveled in Experiment 1. The reaching duration was coded by two independent observers. The inter-observer agreement was high (r = 0.95).

3.3. Results and discussion

Preliminary analysis found no effects of Sex, Block Order, or Trial Type. Subsequent analyses collapsed over these variables. A 2 (Condition: Different Outsides vs. Different Insides) × 3 (Trial Type: 1-Object Box Empty, 2-Objects 1 Remain, 2-Objects Box Empty) ANOVA yielded no significant main effect for Condition, $F(1, 30) = 0.61$, p = .45, $\eta^2 p = .039$, and Trial Type, $F(2, 30) = 1.24$, p = .3, $\eta^2 p = .07$. This analysis also revealed a non-significant interaction, $F(2, 30) = 0.4$, p = .67, $\eta^2 p = .026$.

Planned comparison t-tests across Trial Types in each condition were carried out. In the Different Insides Condition searching duration for 1 Remains (M = 1.85 s, SD = 1.07) and both "box empty" trials (M = 1.55 s, SD = 1.89 for 1-Object Box Empty, and M = 1.84, SD = 2.01 for 2-Objects Box Empty) did not differ significantly, t(15) = 0.704, p = .74, d = 0.19, two-tailed, for 1-Object Box Empty, and t(15) = 0.014, p = .99, d = 0.001, two-tailed for 2-Objects Box Empty (see Fig. 5). In the Different Outsides condition, the comparison between 1 Remains trials and 1-Object Box Empty trials revealed a significant difference, t(15) = 3.28, p = .01, d = 0.82, two-tailed, which resulted from longer search times on 1 Remains trials (M = 2.45 s, SD = 1.44) than on 1-Object Box Empty (M = 1.62, SD = 1.37). However, the comparison between 1 Remains and 2-Objects Box Empty trials (M = 1.99, SD = 1.57) revealed no significant differences, t(15) = 0.98, p = .56, d = 0.25. Finally, the comparison between 1 Remain trials across conditions revealed no significant differences, t(15) = 1.38, p = .19, d = 0.35, two-tailed.

A non-parametric Wilcoxon test confirmed the pattern of results obtained with the planned *t*-test. In the Different Insides condition, the differences between 1 Remain and both "box empty" trials were not
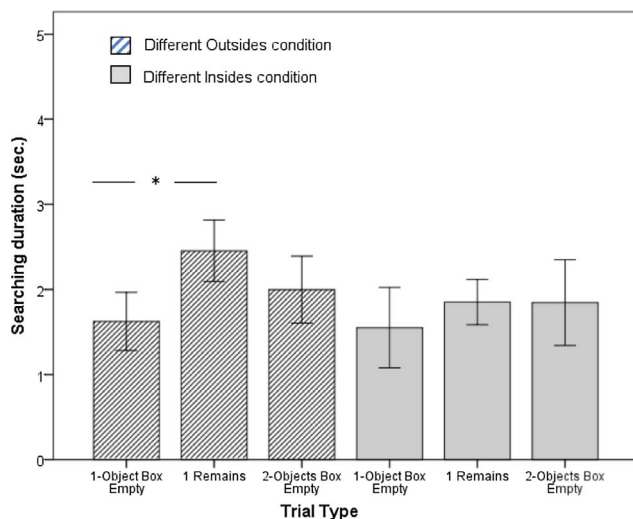
Fig. 5. Searching duration for Experiment 2. Error bars represent standard error of the mean. Asterisks mark statistically significant differences (p < .05).

significant (Z = −0.85, p = .32, for 1-Object Box Empty, and Z = −0.45, p = .44, for 2-Objects Box Empty). In the Different Outsides condition, only the difference between 1 Remains and 1-Object Box Empty was significant (Z = −2.5, p = .01). The difference between 1 Remains trials across conditions revealed a non-significant difference (Z = −1.29, p = .1). Finally, the number of infants who searched longer during 1 Remains trials than in 1 Object Box Empty trials was not significant in the Different Insides condition, (n = 10 out of 16; p = .23, 1-tailed binomial test), but significant in the Different Outsides condition (n = 12 out of 16; p = .037, 1-tailed binomial test). The number of infants who searched longer in the Different Insides condition than in the Different Outsides condition in 1 Remain trials was not significant as well (n = 7 out of 16; p = .4, 1-tailed binomial test).

The comparison between Experiment 1 and 2 shows a significant interaction between Experiment Type and Trial Type in the Different Insides condition, $F(2, 60) = 4.8$, p = .01, $\eta^2 p = .14$, and a non-significant interaction in the Different Outsides condition, $F(2, 60) = 1.1$, p = .33, $\eta^2 p = .03$. These results support the hypothesis that infants individuate two objects in the Different Insides condition only when they display animate and agentive properties.

The results of Experiment 2 revealed that infants are relatively insensitive to the internal property differences that exist between objects that are inanimate. Specifically, we found that manipulating the color of an object's 'insides' on subsequent appearances from the box (i.e., the Different Insides trials) did not affect infants' numerical interpretation of how many individuals were involved in the event. Instead, infants seemed to form a stronger impression of two objects during Different Outsides trials, suggesting that they were more likely to interpret a difference in *external* properties as evidence of there being more than one individual inside the box. Perhaps infants may represent external property differences as more closely related to a change in identity than internal property differences when viewing inanimate objects, although this will require further investigation since the interaction between both conditions was not significant.

The current pattern of results is the opposite of what was found in Experiment 1, which employed nearly identical stimuli that were instead animate agents. In that study infants used the differences between subsequent appearances of an agent's 'insides' to infer a change in individual identity. That is, infants in the Different Insides condition of Experiment 1 reached as if they were expecting two individual agents in the box. Taken together, these results evidence a striking domain difference in infants' sensitivity to internal properties and support the hypothesis that internal features are especially important for

representing the identity of animate and agentive objects, even early in development.

This experiment also rules out several low-level alternative explanations for infants' performance in Experiment 1. Neither the central position nor the 3D structure of the internal properties can account for infants' bias towards 'insides' when individuating agents. However, one related explanation for the observed pattern of results that Experiment 2 does not rule out is that, from a frontal view, the toy's eyes draw attention towards the internal features. Since eyes tend to be a very salient feature from very early in development (e.g., Farroni, Csibra, Simion, & Johnson, 2002) infants might have encoded the color of the insides more robustly based on their proximity to the agent's eyes. This interpretation is somewhat unlikely since the agent's insides are often seen from a side view as the agent travels across the top of the box such that the eyes are not wholly perceived and the external features are more salient than the internal ones. Nevertheless, we conducted a third experiment aimed at controlling for the possibility of a bias toward the eyes. In order to control for this possibility a new set of toys were built with the eyes placed away from the internal properties and closer to the external properties, avoiding any overlap with the eyes from a frontal view (see Fig. 6). If the result from Experiment 1 was due to infants' attention being biased toward the agent's eyes instead of some intrinsic, domain-specific interest in the internal properties, per se, then we should obtain a different pattern of results (e.g., infants' failing to individuate two objects in the Different Insides condition).

4. Experiment 3

4.1. Participants

Sixteen 13-month-old infants participated in this experiment (mean age = 13 months and 11 days, SD = 8 days). Seven of them were girls. All infants were recruited from the Amherst, Massachusetts area. An additional 6 infants were tested but were excluded because of fussiness (1), or disinterest (5). Fussiness and disinterest were operationalized as before.

4.2. Stimuli, design, procedure

The design and procedure for this third experiment was identical to Experiment 1. All six toys were transparent plastic spheres that were covered on the very top with acrylic paint. Inside each sphere attached to the bottom was a small cube made of foam that was visible from the

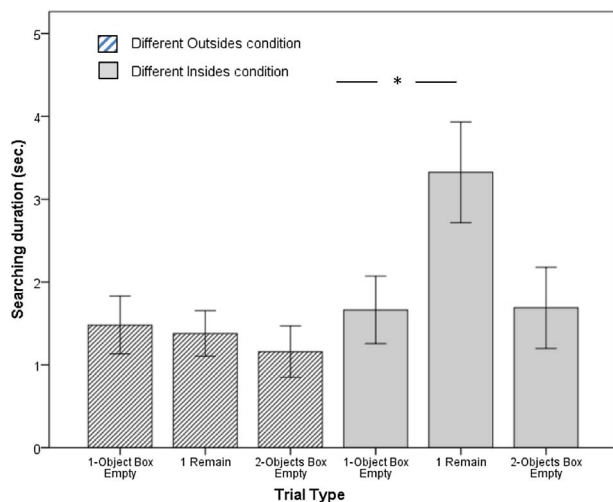**Fig. 6.** An example of the stimuli used in Experiment 3.

Fig. 7. Searching duration for Experiment 3. Error bars represent standard error of the mean. Asterisks mark statistically significant differences (p < .05).

outside. From a front perspective, the total visible surface area that was covered with paint on the outside matched the total visible surface area of the inside cube. All other features of the toy (i.e. the washer, the magnet) were kept the same as in the previous experiments. The same color combination of Experiment 1 was used here. Infants' reaching duration was coded by two independent observers who achieved high inter-observer agreement (r = 0.94).

4.3. Results and discussion

Preliminary analyses found no effects of Sex, Block Order or Test Order; therefore, all three between-subjects effects were collapsed in subsequent analyses. A 2 (Condition: Different Outsides vs. Different Insides) × 3 (Trial Type: 1-Object Box Empty, 2-Objects 1 Remains, 2-Objects Box Empty) analysis of variance (ANOVA) revealed a marginally significant main effect of Condition, $F(1, 30) = 3.37$, p = .086, η^2p = .18, which resulted from longer search times in the Different Insides condition (M = 2.7, SD = 1.87) than in the Different Outsides condition (M = 1.75, SD = 1.3). A main effect of Trial Type was also significant, $F(2, 30) = 4.95$, p = .014, η^2p = .24, due to infants searching longer on 1 Remains trials than on "box empty" trials (see Fig. 7). Finally, there was a Condition X Trial Type interaction, $F(2, 30) = 9.6$, p = .001, η^2p = .37, that was followed-up with planned comparisons t-tests (Bonferroni corrected). In the Different Insides condition, the comparisons between 2-Objects 1 Remains and both "box empty" trials were statistically significant, $t(15) = -3.3$, p = .01, d = 0.88, two-tailed, for 1-Object Box Empty, and $t(15) = 3.78$, p = .004, d = 0.97, two-tailed, for 2-Objects Box Empty, due to infants searching longer on 1-Remains trials (M = 3.32 s, SD = 2.43) than on 1-Object Box Empty (M = 1.66 s, SD = 1.63) and 2-Objects Box Empty trials (M = 1.68 s, SD = 1.95). In the Different Outsides Condition, the comparisons between 2-Objects 1 Remains and both "box empty" trials were non-significant, $t(15) = 0.35$, p = .92, d = 0.1, two-tailed, for 1-Object Box Empty, and $t(15) = 0.61$, p = .79, d = 0.14, two-tailed, for 2-Objects Box Empty (M = 1.38 s, SD = 1.1, for 1 Remains, M = 1.48 s, SD = 1.4, for 1-Object Box Empty, and M = 1.16 s, SD = 1.24, for 2-Objects Box Empty). Finally, the difference between 1 Remains trials across conditions revealed a significant difference, $t(15) = 2.8$, p = .012, d = 0.81, two-tailed, due to infants searching longer on Different Insides trials than in Different Outsides trials.

A non-parametric Wilcoxon test confirmed the pattern of results obtained with the planned t-tests. In the Different Insides condition, the differences between 1 Remains and both "box empty" trials were significant (Z = −2.69, p = .017, for 1-Object Box Empty, and Z = 2.67,

p = .02, for 2-Objects Box Empty). By contrast, in the Different Outsides condition, the differences between 1 Remains and both "box empty" trials were non-significant (Z = −0.51, p = .49 for 1-Object Box Empty, and Z = 0.37, p = .5 for 2-Objects Box Empty). The difference between 1 Remain trials across conditions revealed a significant difference (Z = 2.38, p = .041). Finally, the number of infants who searched longer during 1 Remains trials than in 1 Object Box Empty trials was significant in the Different Insides condition, (n = 13 out of 16; p = .01, 1-tailed, via a binomial test), but not significant in the Different Outsides condition (n = 7 out of 16; p = .4, 1-tailed, via a binomial test). The number of infants who searched longer in the Different Insides condition than in the Different Outsides condition in 1 Remains trials was significant (n = 12 out of 16; p = .037, 1-tailed, via a binomial test).

The comparison between Experiment 2 and 3 shows a significant interaction between Experiment Type and Trial Type in the Different Insides condition, $F(2, 60) = 3.25$, p = .046, η^2p = .1, and a non-significant interaction in the Different Outsides condition, $F(2, 60) = 1.66$, p = .2, η^2p = .05. Thus, like the comparison between Experiment 1 and 2, these results suggest that infants have a stronger representation of two agents in the Different Insides condition of Experiment 3, presumably because those agents display animate and agentive behavior.

The results of Experiment 3 replicate the main findings of Experiment 1. Specifically, we found that manipulating the color of an agent's 'insides' on subsequent appearances from the box (i.e., the Different Insides trials) significantly affected infants' numerical interpretation of how many individuals were involved in the event. When the agent's internal properties were different from one moment to the next infants were more likely to reach as if two individuals were in the box. Once again, when the agents possessed the same color insides infants failed to individuate two agents. Furthermore, we replicated this pattern of results despite the fact that the agent's eyes never overlapped with their internal properties.

5. General discussion

The current experiments used an individuation task to investigate a possible internal feature bias in infants' representations of agent identity. Experiment 1 found that infants individuate agents (e.g., objects with self-propelled motion and agentive features such as eyes) using the color of their *internal* properties, while they tend to disregard the color of their external properties. By contrast, in Experiment 2 we found that infants fail to use internal property differences to individuate objects that lack both self-propelled motion and agentive features but are otherwise identical to the agents. This pattern of results indicates that the agent's insides in Experiment 1 were not more salient due to either their central position within the object's body or their complexity (e.g., their 3D structure). Experiment 3 replicated the results of Experiment 1 while controlling for the position of the eyes relative to the agent's internal properties, thereby ruling out the possibility that infants' sensitivity to an agent's 'insides' is due to a more general attraction to an agent's eyes. These findings suggest that infants represent internal physical properties as more closely connected to agent identity than external properties. Instead of employing a domain-general criterion of similarity to represent an agent's persisting identity over time, the current data suggest that infants use domain-specific biological knowledge, where physical insides are especially relevant for determining the identity of agents and not inanimate objects.

Why might infants represent internal physical features as more diagnostic of an agent's identity than its external features? One possible explanation has to do with the causal role that infants may attribute to the insides when observing the objects moving on the top of the box. For instance, as indicated by Setoh et al. (2013), infants only infer the presence of something inside an object when it displays self-propelled motion *and* agentive features, which suggests that infants represent 'insides' as a biological and causal factor in order to explain both

motion and agency (the "Innards Principle"). In the current study, even though infants can clearly observe the presence of 'insides' in all conditions, they might only represent them as having a causal role, thereby making them relevant for individuation decisions, when the objects display both self-propulsion and agency. The lack of one or both of these properties may lead infants to construe those objects as non-biological agents (e.g., Opfer, 2002), stripping the internal physical properties of their biological and causal role. Two such cues to agency were subtracted in our second experiment (self-propelled motion and eyes) but future studies could test each of these variables independently to assess whether either is sufficient for creating a bias towards internal properties in infants' individuation judgments.

Other evidence connecting internal properties with notions of causality comes from studies with adults and preschool-aged children where the "causal factors" are shown to be more central in the conceptual representation than so-called 'effect factors' (Ahn, 1998; Ahn, Gelman, Amsterlaw, Hohenstein, & Kalish, 2000). For instance, several categorization studies have shown that causal factors (e.g. goat DNA) are more reliable indicators of category membership than effect factors (e.g. give milk; Rehder, 2003; Sloman, 2005). Similarly, an agent's physical 'insides' may serve as a causal placeholder in infants' early representation of agents, making the internal physical features in the current study more diagnostic of a change in identity than the agent's external features.

If the previous interpretation is correct, why do infants represent the insides as something causally relevant and connected to the agents' identity and what are the consequences of this interpretation across development? Setoh et al. (2013) propose that the inference of insides arises from an ancient cognitive mechanism devoted to detect possible prey, in such a way that the insides of prey are conceptualized as valuable sources of nutrients. Although feasible, this interpretation does not provide an explanation about why the insides seem to be especially informative for representing an agent's identity, per se. A second possibility could be that the inference of internal and causally-relevant properties arises from an early tendency to categorize objects into kinds, which would be consistent with an essentialist bias in infancy (Cacchione, Schaub, & Rakoczy, 2013; Futo, Teglas, Csibra, & Gergely, 2010; Gergely & Jacob, 2012; Xu, 2005). Several studies have revealed that from early on in development children determine an object's categorical identity on the basis of the non-obvious properties it possesses. For example, infants expect objects categorized with the same label to share a non-obvious property regardless of their physical similarity (Dewar & Xu, 2009; Graham & Kilbreath, 2007), and conversely, preschool aged children expect dissimilar objects with identical, non-obvious, causal powers to share the same label (Gopnik & Nazzi, 2003). However, in infancy the knowledge of insides as causally relevant, non-obvious, properties seems to be specific to biological kinds insofar as the causal role of insides in artifacts emerges later on (Sobel & Munro, 2009; Sobel, Yoachim, Gopnick, Meltzoff, & Blumenthal, 2007). Consequently, the association between an agent's insides and their identity that emerged in the current study may be the result of an early understanding of insides as a *biological kind-relevant property* that possesses more information than the outsides about the categorical identity of a particular agent (for a review, see Taborda-Osorio & Cheries, 2017). This understanding, in turn, may be further elaborated across development giving rise to more specific expectations in such a way that different biological kinds are attributed Different Insides with particular causal powers (Keil, 1989). For instance, even 3-year-olds use internal properties rather than functional information or external properties to categorize animals (Diesendruck, 2001; Diesendruck & Peretz, 2013), suggesting an early understanding of the link between animals' internal physical properties and kind membership. Whether this same notion is already present at the start of the second year of life or it is developed and enriched afterwards will be a matter of further research.

Another point that will deserve further investigation is how infants *spontaneously* represent animals' internal properties. In the current set of experiments, an object (a small cube) inside another object (a transparent sphere) was used to materialize the idea of internal physical properties. However, the ability to use the features we provided does not necessarily entail that infants automatically infer such features *in advance* when viewing other agents that are normally opaque. Some authors (Newman & Keil, 2008; Wynn, 2008) have argued that young children may exhibit a bias to represent the "essence" of biological entities in a similar localized manner. For instance, 6-year-old children believe that an animal's kind membership can best be determined by looking at a specific location inside its body rather than by looking at distributed internal features (Newman & Keil, 2008). Of course, it is an open question whether infants' concept of insides is as specific and concrete as this. An alternative is that infants may represent animals as made of some kind of non-discrete material that affords animacy (e.g., Subrahmanyam, Gelman, & Lafosse, 2002). In this way, infants might infer that the internal cause of the agent's identity is non-localized and distributed throughout the insides. Finally, and most abstractly, infants might be agnostic about whether the physical insides are discrete or distributed and instead attribute an agent's identity to a kind of intrinsic energy that is responsible for its phenomenal properties but one that is not necessarily linked to any specific material component, per se. This understanding would be closer to what some psychologist call an essential placeholder (Medin & Ortony, 1989). In all of these cases, infants' attention is still drawn towards an animal's internal constitution in virtue of them being self-propelled and goal-directed entities, such that the internal properties used in the current study served as an adequate proxy for their ideas about biological kind-relevant properties.

Finally, the current studies may help inform our understanding of infants' individuation judgments, more generally. For example, the fact that infants in Experiment 1 and 3 succeeded in individuating agents by the color of their internal properties seems at odds with previous findings showing that 12-month-olds fail to individuate based on color alone (Xu et al., 2004). However, participants in our study are one month older and, perhaps more importantly, objects in Experiments 1 & 3 displayed self-propelled motion and possess agentive features (eyes). This could improve infants' performance in at least two different ways. First, these features may make the stimuli much more engaging than when only observing inanimate objects. Second, and most substantively, infants may individuate by color in our experiments because of this feature is perceived as being meaningful in the current context—the 'insides' of living things may provide meaningful information about its identity. This may be due to infants' intuitive understanding that internal properties have a causal role in the agents' self-propelled and agentive motion. By contrast, in Experiment 2 neither the color of the internal or the external properties had a causal role in the objects' motion. This explanation is in line with previous studies about color priming by object function (Wilcox & Chapa, 2004; Wilcox & Biondi, 2015), showing that 9-month-olds are primed to use color to individuate objects when they are presented with events in which objects are engaged in meaningful causal relations, but not when objects are merely associated to different types of motion. Future work should further examine the role of such domain-specific biases and how different properties might affect infants' individuation decisions differently depending upon the kind of stimuli that are used.

6. Conclusion

The current studies demonstrate 13-month-old infants' bias to use an agent's visible internal features (rather than its external features) to represent its individual identity over time. This internal property bias was apparent for agents but not for inanimate objects. The link between insides and identity may be the result of an implicit understanding of an agent's internal features as biological properties that are causally related to self-propelled motion and agentive behavior. Infants' bias to represent internal features as reliable cues for individuation may serve

as part of the foundation for kind concept representations and essentialist intuitions about biological entities.

Acknowledgments

Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.cognition.2018.01.016.

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